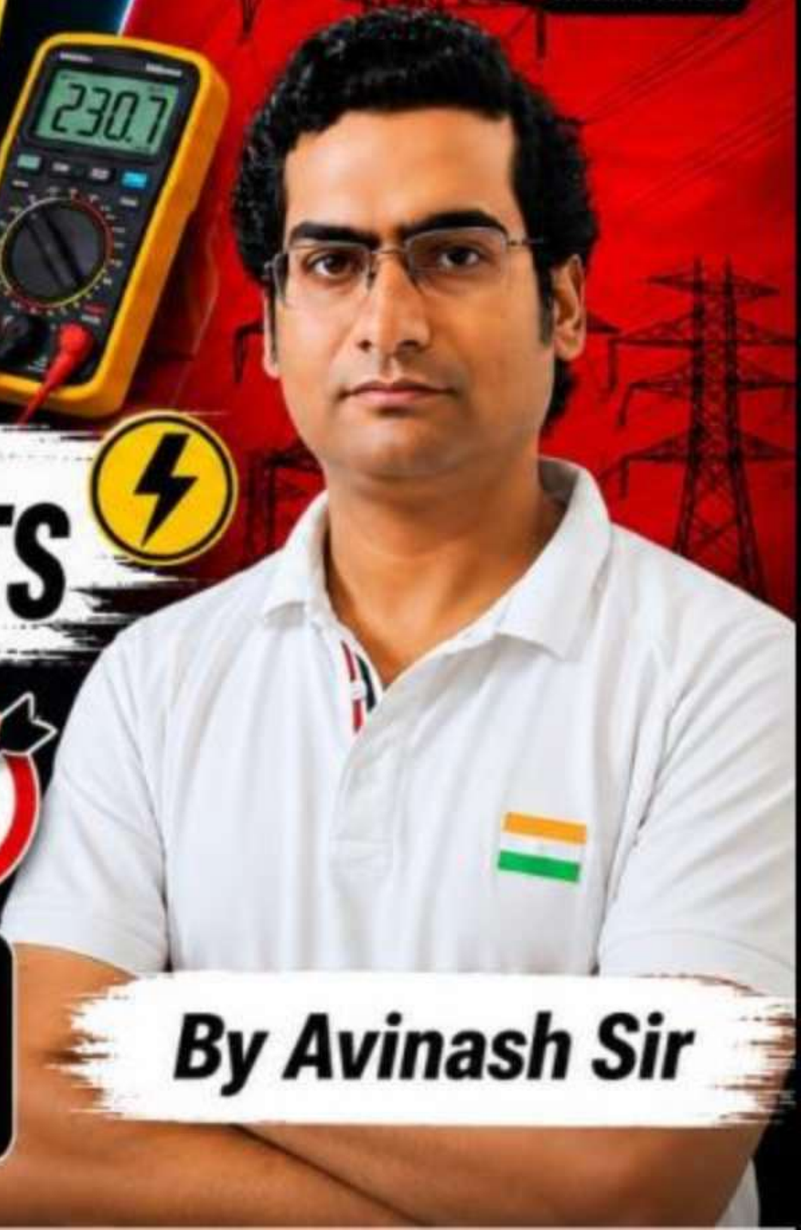
AKTU B.TECH

SEM-3 EE & ALLIED

EMI – ELECTRICAL MEASUREMENTS & INSTRUMENTS

UNIT-2 ONE SHOT



GW GATEWAY CLASSES

COMPLETE NOTES | AKTU PYQs | IMPORTANT QUESTIONS

By Avinash Sir

UNIT II SYLLABUS
MEASURMENT OF POWER & ENERGY

MEASURMENT OF POWER & ENERGY:

Types of watt meters, Single phase dynamometer & induction type wattmeter, Expression for deflecting and control torques. Measurement of active and reactive power in balanced and unbalanced three phase systems, theory and operation of single & three phase induction type energy meter, power factor meter & analog frequency meter.

4
2 wattmeter method
3
1
any one 1

Types of Wattmeter's

A wattmeter is an instrument which is used to measure electric power given to or developed by an electrical circuit. Generally, a wattmeter consists of a current coil and a potential coil.

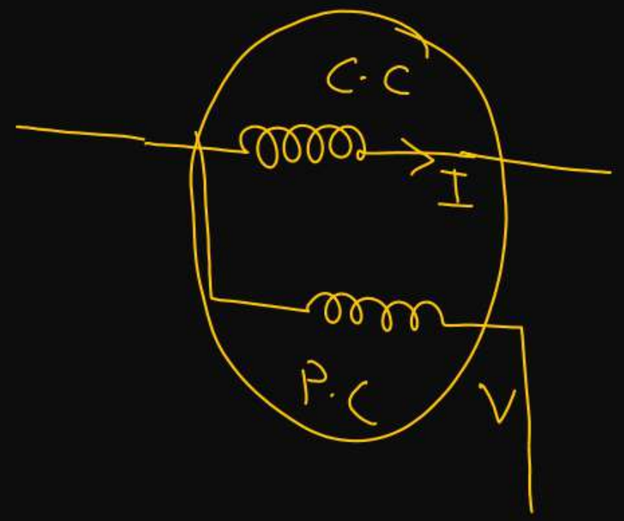
Types of Wattmeter

Electrodynamometer wattmeter– for both DC and AC power measurement

Induction wattmeter – for AC power measurement only

- **Ferro dynamic wattmeter**
- **Low power Factor wattmeter**
- **Thermocouple Wattmeter**

$P = VI$



Imp Ques-(1)

Electrodynamometer wattmeter

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Fixed Coil:- It is connected in series with the load, which is considered as the current coil. It produces a uniform electric field.

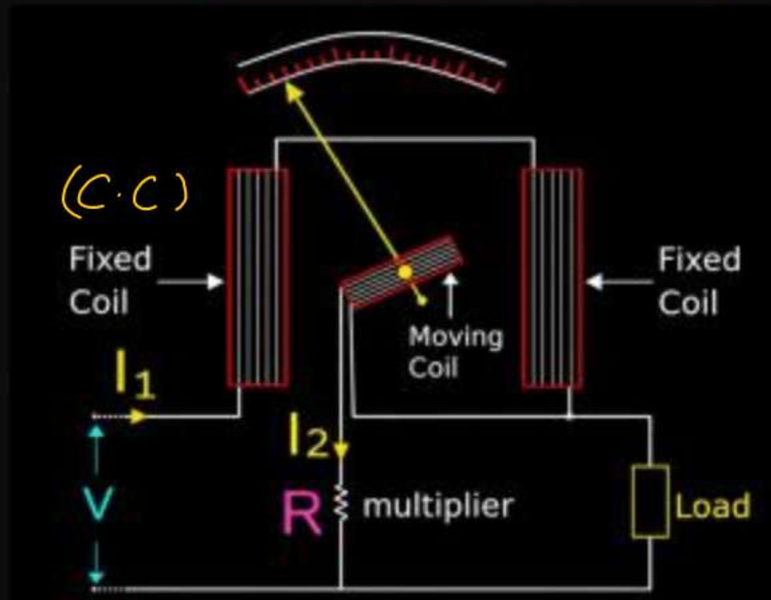
Moving Coil (Pressure Coil):- Connected parallel with the supply voltage. So, that current flows directly proportional to supply voltage. A pointer is mounted on the moving coil with the help of spring to control the movement. To control the flow of the current resistor is connected in series with the moving coil.

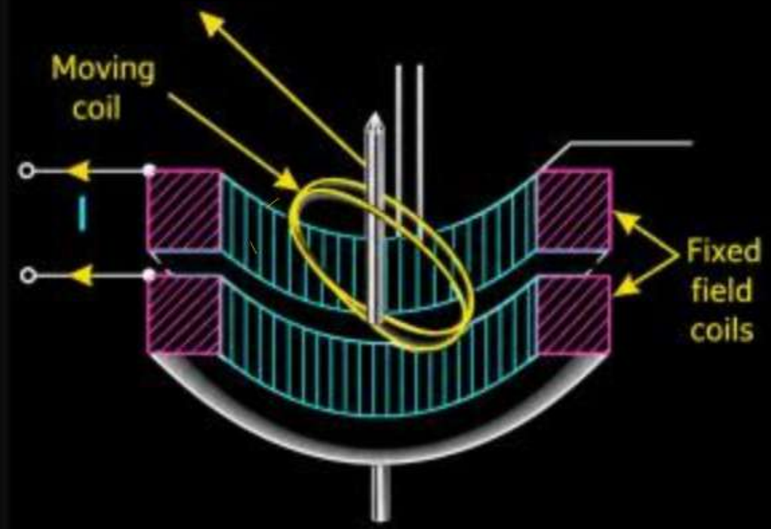
Control:- spring control is used.

Damping:- Air damping is used . Other types of damping are not used as they destroy the useful magnetic flux.

Scales and Pointers

It uses a mirror type linear scale as the moving coil moves linearly. The apparatus uses knife-edge pointers in order to remove parallax error caused due to oversights.

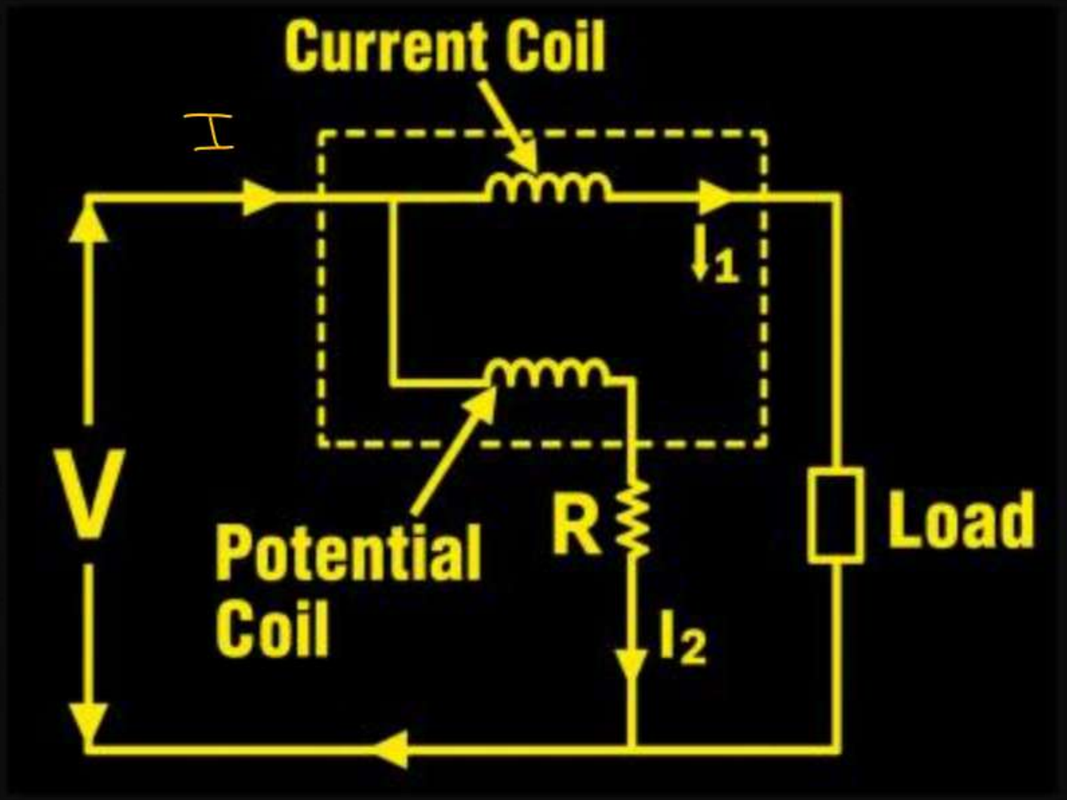




Electrodynamometer wattmeter

Working:-

- The current coil carries the load current and the potential coil carries a current proportional to the load voltage.
- Because of the current in the two coils, a mechanical force acts between them due to which the moving coil (potential coil) moves and hence the pointer attached to it
- When the current is reversed in the circuit, the reversal of current takes place in both the current coil and potential coil so that the direction of the deflecting torque remains unchanged.
- Hence, the electrodynamometer wattmeter can be used for the measurement of DC as well as AC power.



Electrodynamometer wattmeter

Torque Equation:-

In Case of D.C

Torque $T \propto I_1 I_2$

and $I_2 \propto V$

so $T \propto V \cdot I_1 \propto$ Power

In Case of A.C.

$v = V_m \sin \omega t = \sqrt{2} V \sin \omega t$

$I_1 = I_m \sin(\omega t - \phi) = \sqrt{2} I_1 \sin(\omega t - \phi)$

$I_2 = \sqrt{2} I_2 \sin \omega t$

Instantaneous deflecting torque

$T_d \propto I_1 I_2 \frac{dM}{d\theta}$

$T_d \propto \sqrt{2} I_2 \sin \omega t \sqrt{2} I_1 \sin(\omega t - \phi) \frac{dM}{d\theta}$

$T_d \propto 2 I_1 I_2 \sin \omega t \sin(\omega t - \phi) \frac{dM}{d\theta}$ (a → ωt, b → $\omega t - \phi$)

$T_d \propto I_1 I_2 [\cos(\omega t - \omega t + \phi) + \cos(2\omega t - \phi)] \frac{dM}{d\theta}$ ($\cos(a-b)$, $\cos(a+b)$)

$T_d \propto I_1 I_2 [\cos\phi + \cos(2\omega t - \phi)] \frac{dM}{d\theta}$

Average Torque for one Cycle

$T_d \propto \frac{1}{T} \int_0^T I_1 I_2 \frac{dM}{d\theta} [\cos\phi - \cos(2\omega t - \phi)] d\omega t$ (second term → 0)

$T_d \propto \frac{1}{T} (I_1 I_2 \frac{dM}{d\theta}) \left[\int_0^T \cos\phi \, d\omega t - \int_0^T \cos(2\omega t - \phi) d\omega t \right]$ (second integral → 0)

$T_d \propto \frac{1}{T} I_1 I_2 \frac{dM}{d\theta} \cos\phi \int_0^T 1 \cdot d\omega t$

$T_d \propto \frac{1}{T} I_1 I_2 \frac{dM}{d\theta} \cos\phi \, [T]$

$T_d \propto I_1 I_2 \cos\phi \frac{dM}{d\theta}$

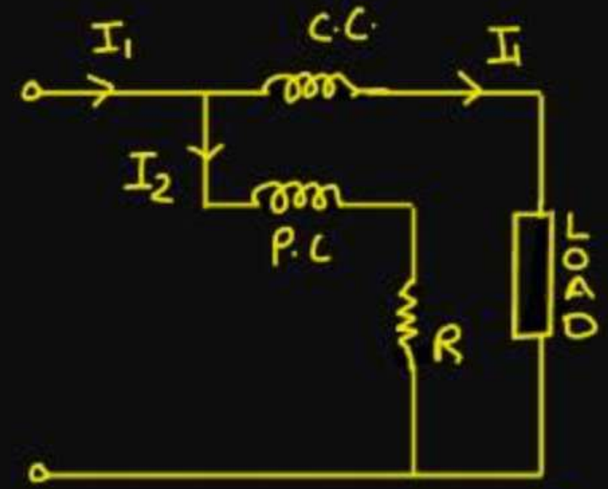
Controlling Torque (spring)

$T_c \propto \theta$, $T_c = K\theta$

For equilibrium $T_c = T_d$

$K\theta = K' I_1 I_2 \cos\phi \frac{dM}{d\theta}$

$\theta = K'' I_1 \frac{V}{R} \cos\phi \, dM/d\theta$



$\theta = K'' V I_1 \cos\phi \frac{dM}{d\theta}$

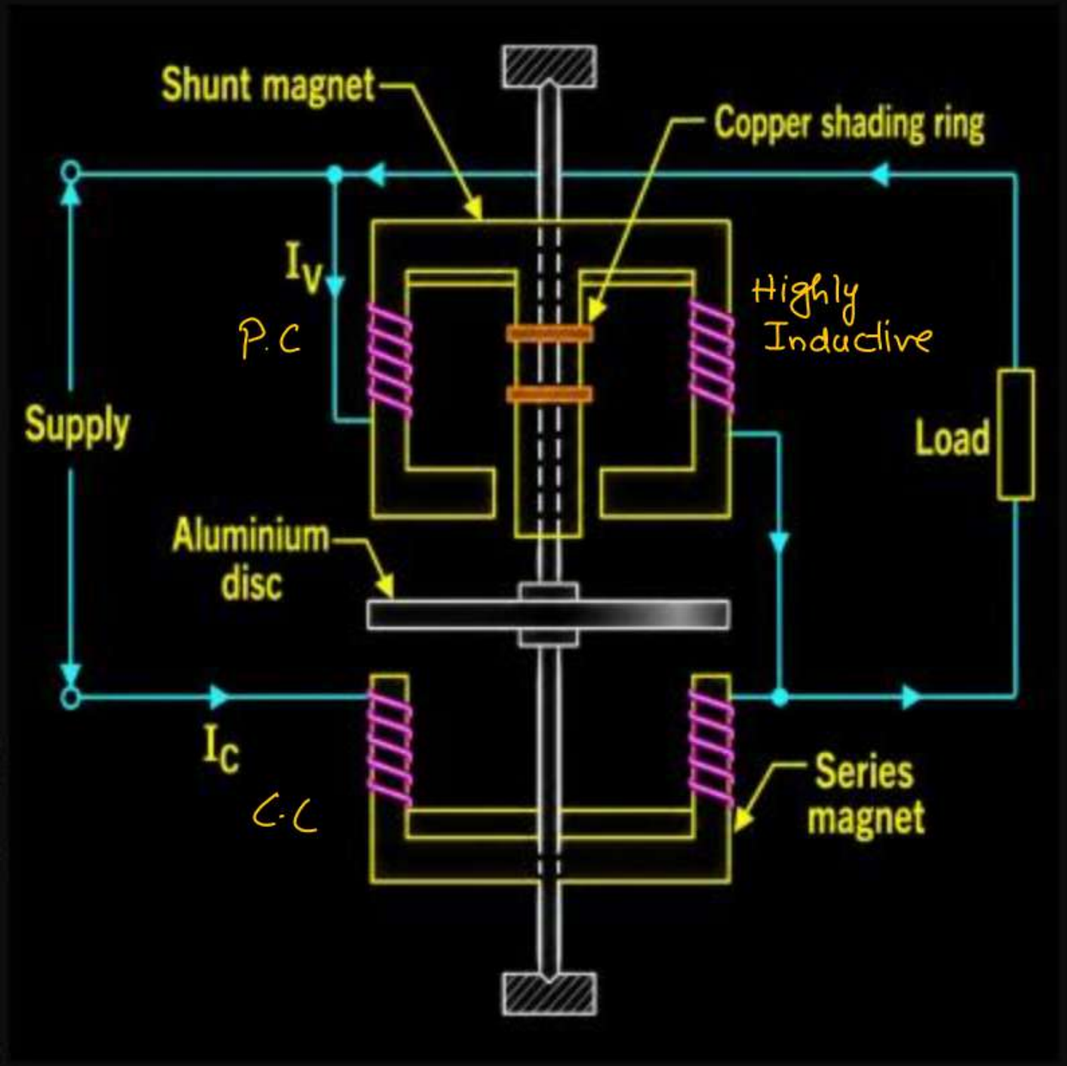
or

$\theta \propto V I_1 \cos\phi \frac{dM}{d\theta}$

$\theta \propto$ Power $\times \frac{dM}{d\theta}$

Induction type wattmeter

- The induction type wattmeter can be used to measure a.c. power only
- The induction wattmeter consists of two laminated electromagnets. *Shunt Magnet and Series Magnet*.
- The shunt magnet is connected across the supply and carries a current proportional to the supply voltage.
- The coil of shunt magnet is made highly inductive so that the current in it lags the supply voltage by 90°.
- The series magnet is connected in series with the supply and carries the load current. The coil of series magnet is made highly non-inductive.
- A thin disc mounted on a spindle is placed between the two magnets so that it cuts the flux of the two magnets.



Imp. Q.2

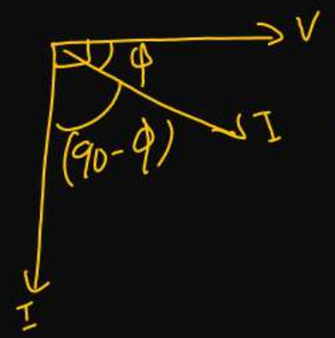
Induction type wattmeter

- When the wattmeter is to measure a.c. power, the shunt magnet carries current proportional to the supply voltage and the series magnet carries the load current.
- The two fluxes produced by the magnets induce eddy currents in the aluminium disc.
- The interaction between the fluxes and eddy currents produces the deflecting torque on the disc, causing the pointer connected to the moving system to move over the scale.
- The pointer comes to rest at a position where deflecting torque is equal to the controlling torque.

Torque Equation:- $T_d \propto \phi_N \phi_c \sin\theta$

$\propto \frac{V}{R} I_c \sin(90-\phi)$

$T_d \propto V I_c \cos\phi \propto$ A.C. Power



$\theta = K''$ A.C. Power

or

$\theta \propto$ A.C. Power

Spring Control, $T_c = K\theta$

For Equilibrium $T_d = T_c$

$K\theta = K' V I_c \cos\phi$

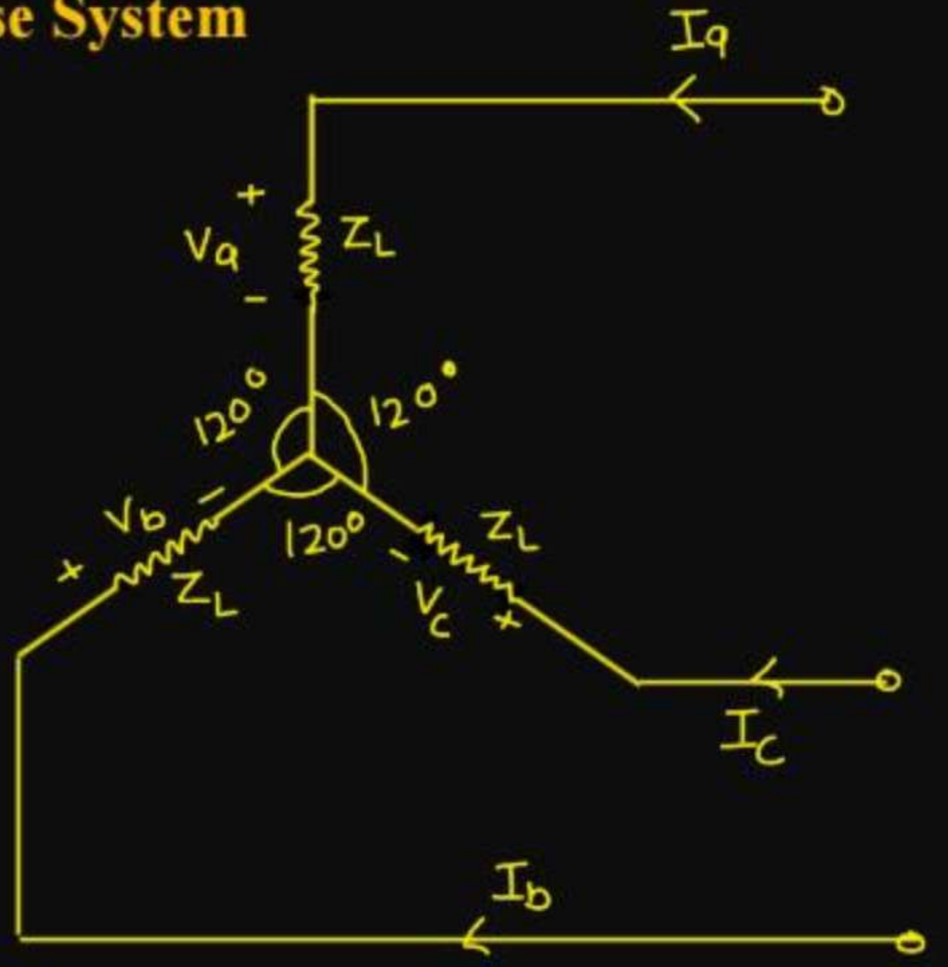
Balanced and unbalanced three phase System

Balanced Load :-

⇒ All phase are equally spaced (120°)

⇒ Magnitude of each phase are equal.

⇒ Impedance of each phase are equal.



Measurement of power in a three phase System

1. Three wattmeter method (3 phase 4 wire System

This method Can be used for Balanced or unbalanced Load.

$$W_1 = P_1 = V_1 I_1 \cos\theta_1$$

$$W_2 = P_2 = V_2 I_2 \cos\theta_2$$

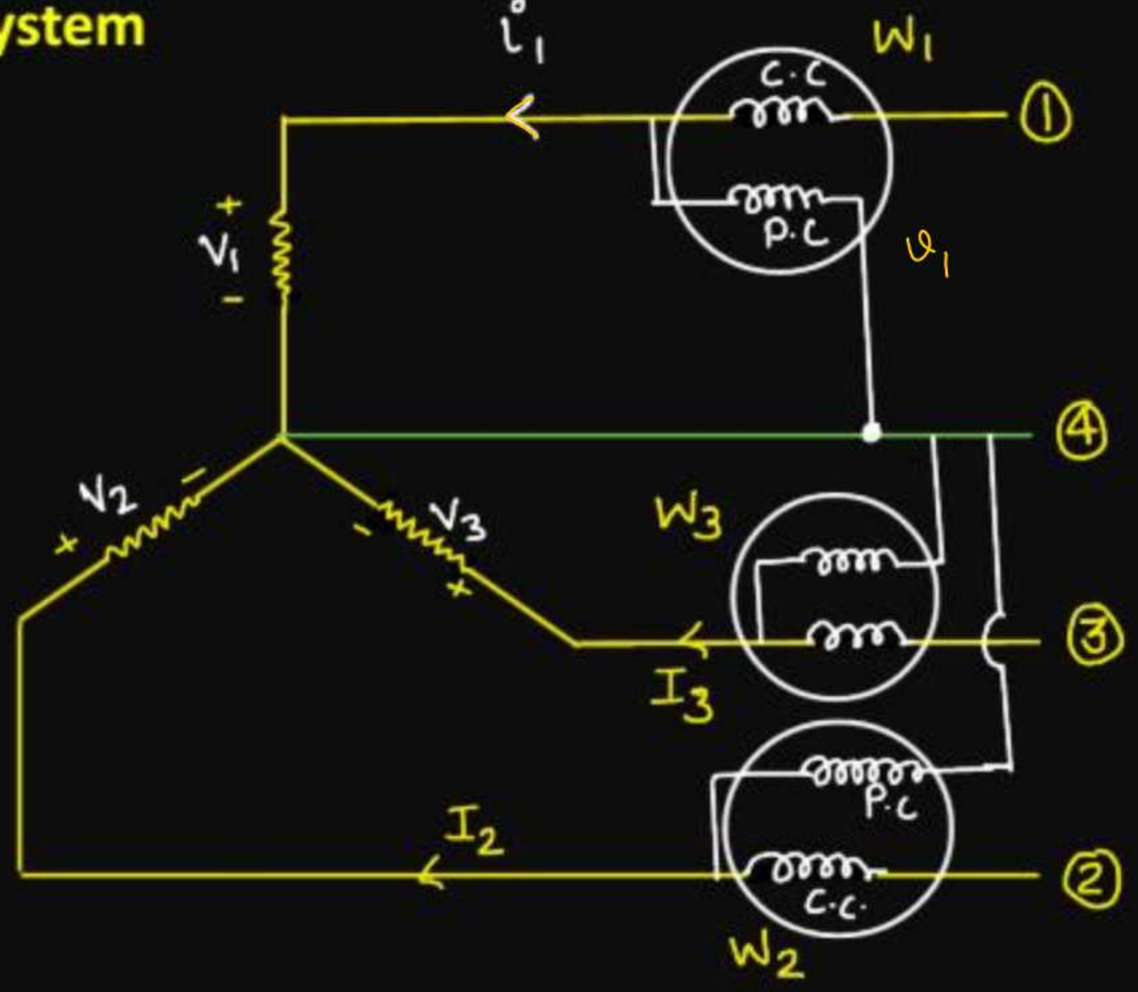
$$W_3 = P_3 = V_3 I_3 \cos\theta_3$$

Total Power measured

$$P = P_1 + P_2 + P_3$$

or

$$P = W_1 + W_2 + W_3$$



Measurement of power in a three phase System

2. Three wattmeter method (3 phase 3 wire System)

$$\begin{cases} v_1 = v_1' + v \\ \text{or } v_1' = v_1 - v \end{cases}$$

From wattmeter (W_1), $P_1 = i_1 v_1' = i_1 (v_1 - v)$ — ①

Similarly For W_2 and W_3

$W_2 = P_2 = i_2 v_2' = i_2 (v_2 - v)$ — ②

$W_3 = P_3 = i_3 v_3' = i_3 (v_3 - v)$ — ③

Total Power

$P = W_1 + W_2 + W_3$

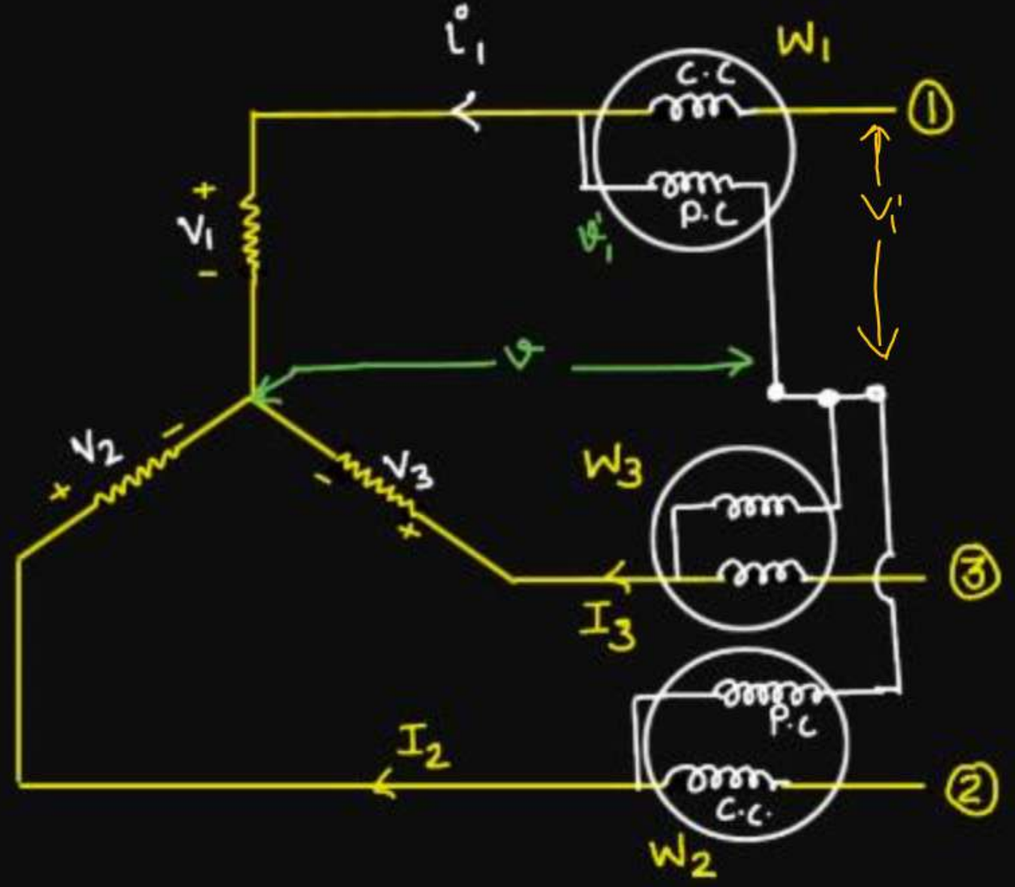
$= \underbrace{i_1 v_1}_{P_1} - i_1 v + \underbrace{i_2 v_2}_{P_2} - i_2 v + \underbrace{i_3 v_3}_{P_3} - i_3 v$

$= (P_1 + P_2 + P_3) - v(i_1 + i_2 + i_3)$

$i_1 + i_2 + i_3 = 0$

or

$$\boxed{P = P_1 + P_2 + P_3} = W$$



V-Imp (3)

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2. Two wattmeter method (Star Connection)

Reading of wattmeter $W_1 = I_1^{\circ} (V_1 - V_3)$

Reading of wattmeter $W_2 = I_2^{\circ} (V_2 - V_3)$ ✓

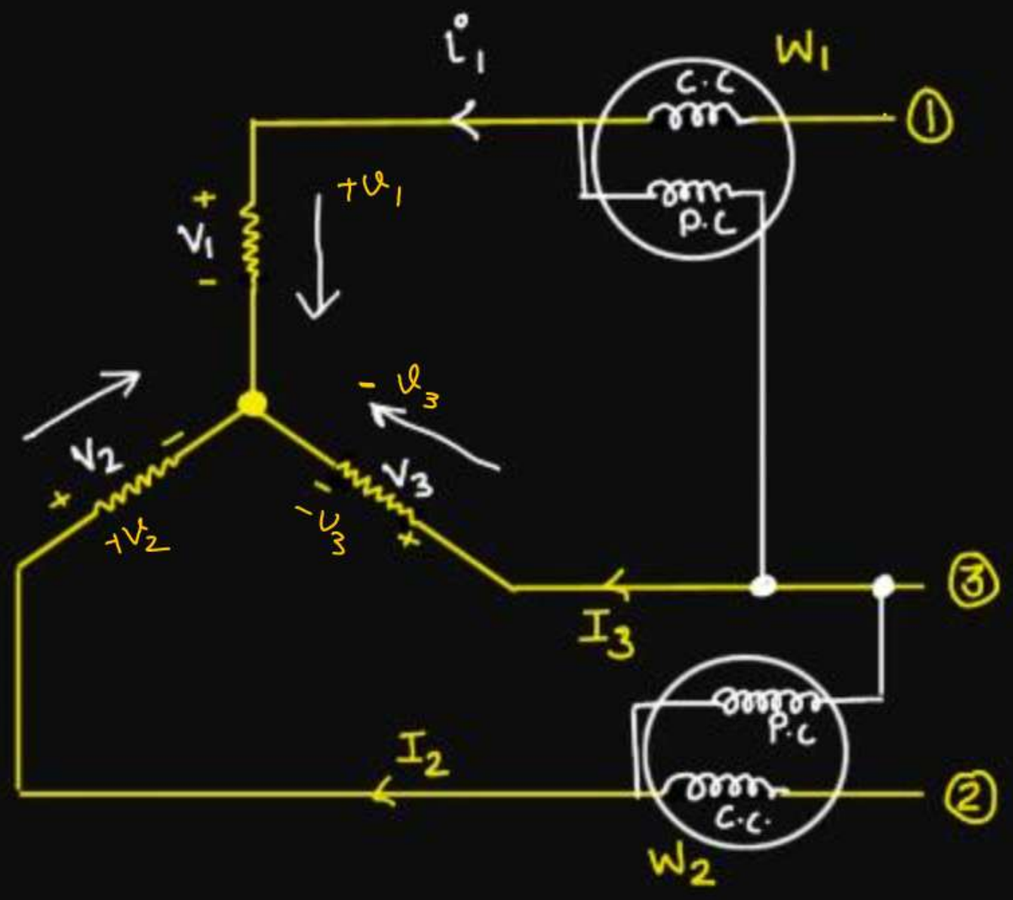
Total Power $= W_1 + W_2 = \underbrace{V_1 I_1^{\circ}}_{P_1} - V_3 I_1^{\circ} + \underbrace{V_2 I_2^{\circ}}_{P_2} - I_2^{\circ} V_3$

$= P_1 + P_2 - V_3 (I_1^{\circ} + I_2^{\circ})$

$= P_1 + P_2 + V_3 I_3^{\circ}$ (P_3) ← $\because I_1^{\circ} + I_2^{\circ} + I_3^{\circ} = 0$, $I_1 + I_2 = -I_3$

So

$P = P_1 + P_2 + P_3 = 3\text{-}\phi$ Power



Measurement of power in a three phase System

2. Two wattmeter method (Delta Connection)

Reading of $W_1 = -(i_1 - i_3) v_3$

Reading of $W_2 = (i_2 - i_1) v_2$

Total $W = W_1 + W_2$

$$W = -i_1 v_3 + i_3 v_3 + i_2 v_2 - i_1 v_2$$

P_3 P_2

$$W = P_2 + P_3 - i_1 (v_2 + v_3) \quad \text{— (1)}$$

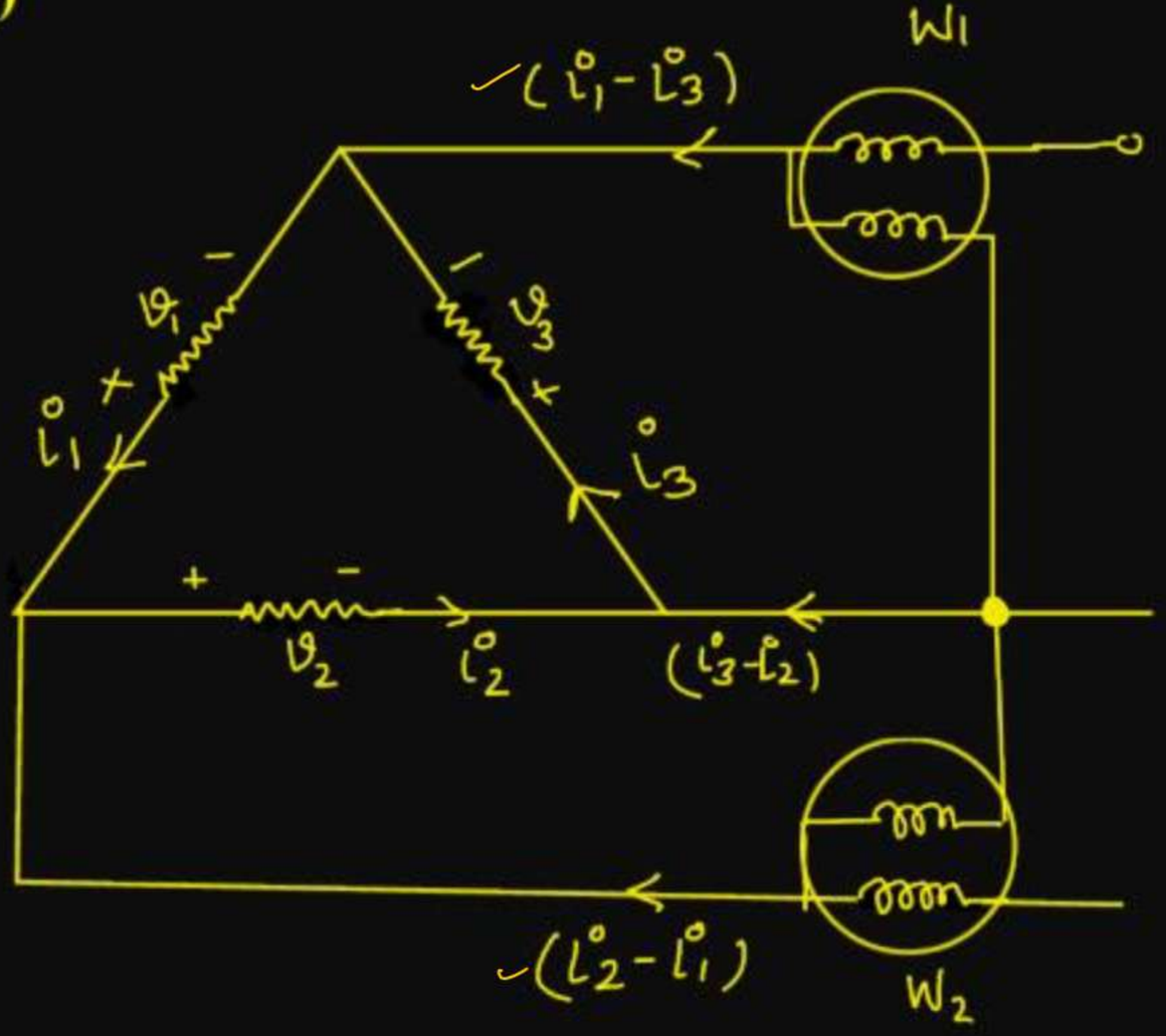
But According to KVL

$$V_1 + V_2 + V_3 = 0 \text{ , or } v_2 + v_3 = -v_1$$

So from Equ (1)

$$W = P_2 + P_3 - i_1 (-v_1) = P_2 + P_3 + v_1 i_1$$

$$\boxed{W = P_1 + P_2 + P_3 = \text{Total 3-}\phi \text{ Power}}$$



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Q.1 Two wattmeter are connected to measure the power consumed by 3-phase balanced load. One of the wattmeter read 1500 W and the other 700W. Find power factor of the load, when (a) both the reading are positive (b) when the reading of the second wattmeter is obtained after reversing its current coil connection.

Soln From Two wattmeter method

$$\tan\phi = \frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}$$

(a) when both wattmeter reading is +ve

$W_1 = 1500\,W$, $W_2 = 700\,W$

$$\tan\phi = \frac{\sqrt{3}(1500 - 700)}{1500 + 700} = 0.6298$$

$$\boxed{\phi = 32.2^\circ}$$

$$P.F = \cos 32.2^\circ = 0.846 \text{ (lag.)}$$

(b) when reading of 2nd wattmeter reversed

$W_1 = 1500\,W$, $W_2 = -700\,W$

$$\tan\phi = \frac{\sqrt{3}(1500 + 700)}{1500 - 700} = 4.763$$

$$\phi = \tan^{-1}(4.763)$$

$$\phi = 78.15^\circ$$

Power factor $\cos\phi = \cos 78.15^\circ = 0.205$ (lag)

Measurement of Reactive power in a three phase System

1. Single phase Varmeters:-

Considering that potential coil (P.C.) is highly inductive

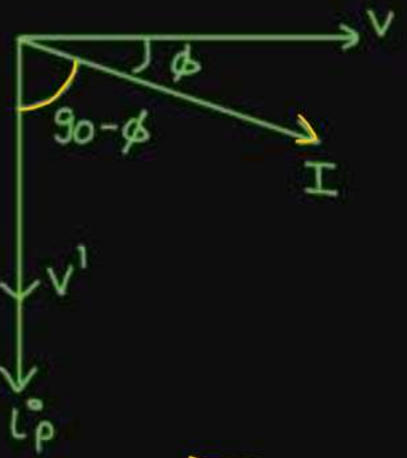
Reading of wattmeter

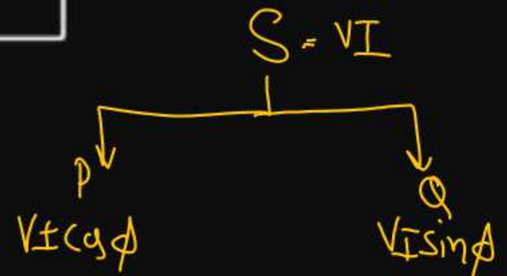
$W = V' I \cos(90-\phi)$

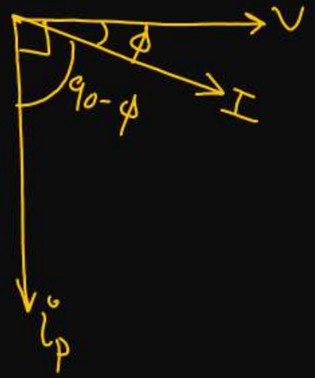
or

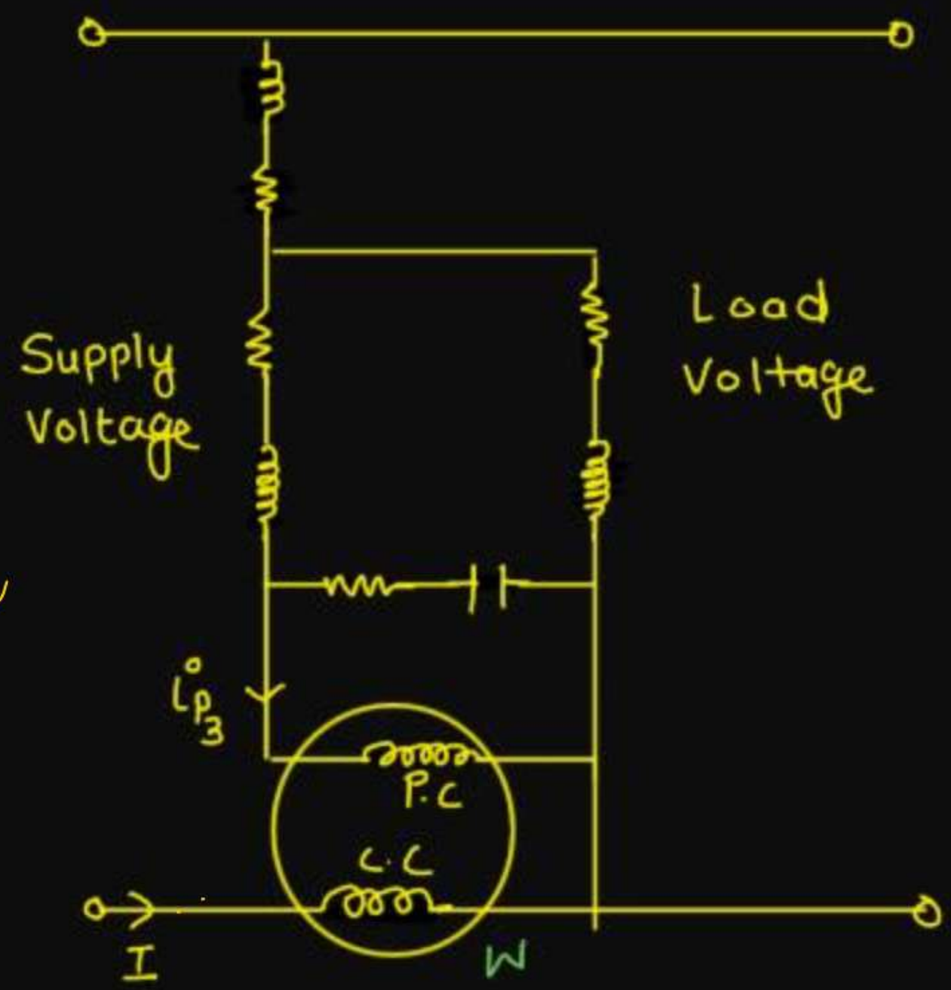
$W = VI \sin\phi$

W = Reactive Power



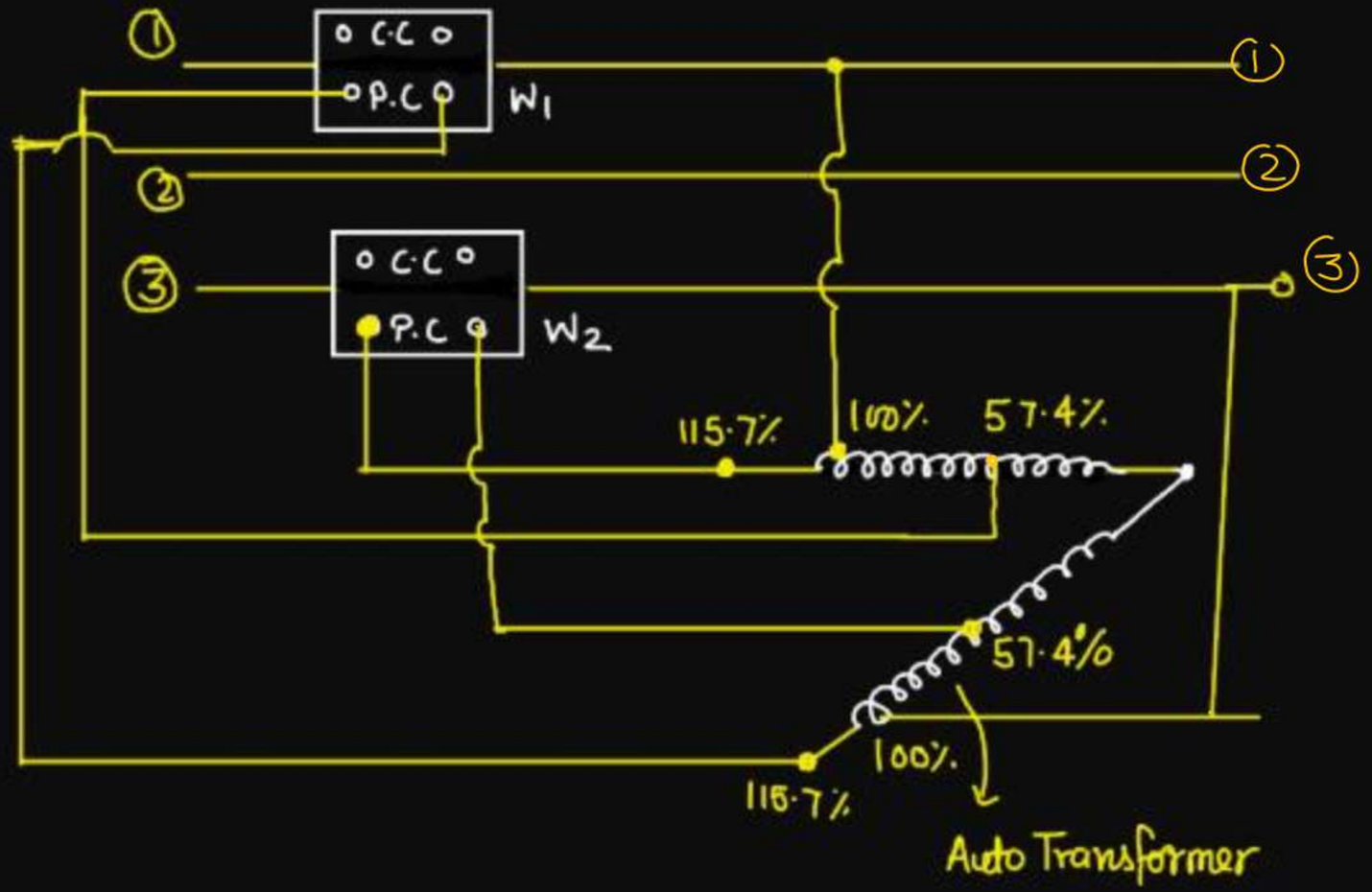


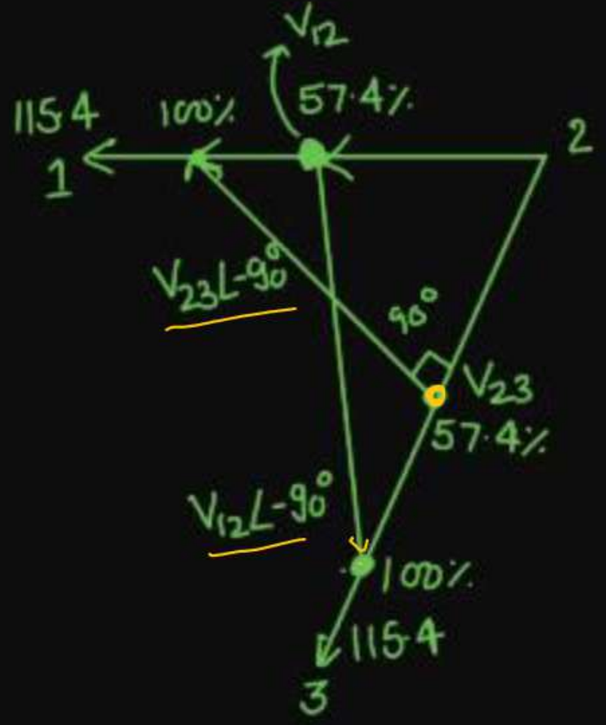




Measurement of Reactive power in a three phase System

2. Polyphase Varmeters:-



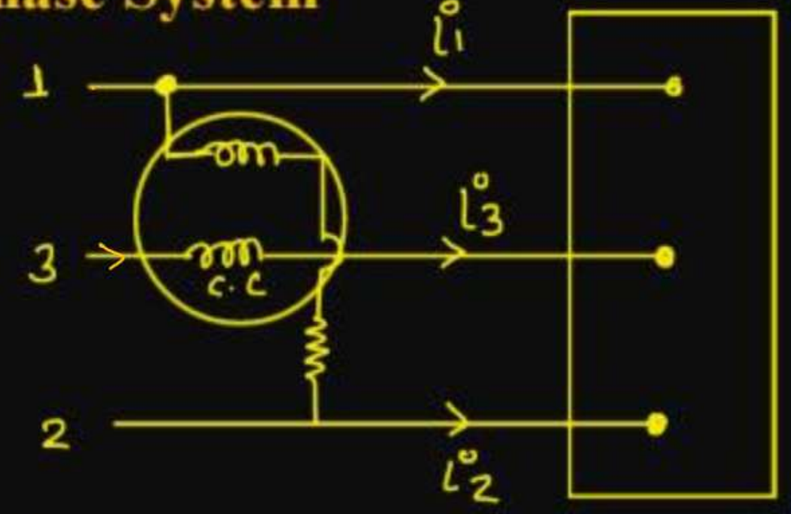


$W = W_1 + W_2$

= Total 3-ϕ Reactive power

Measurement of Reactive power in a three phase System

3. Reactive power Measurement in three phase Circuits:-



Reading of wattmete

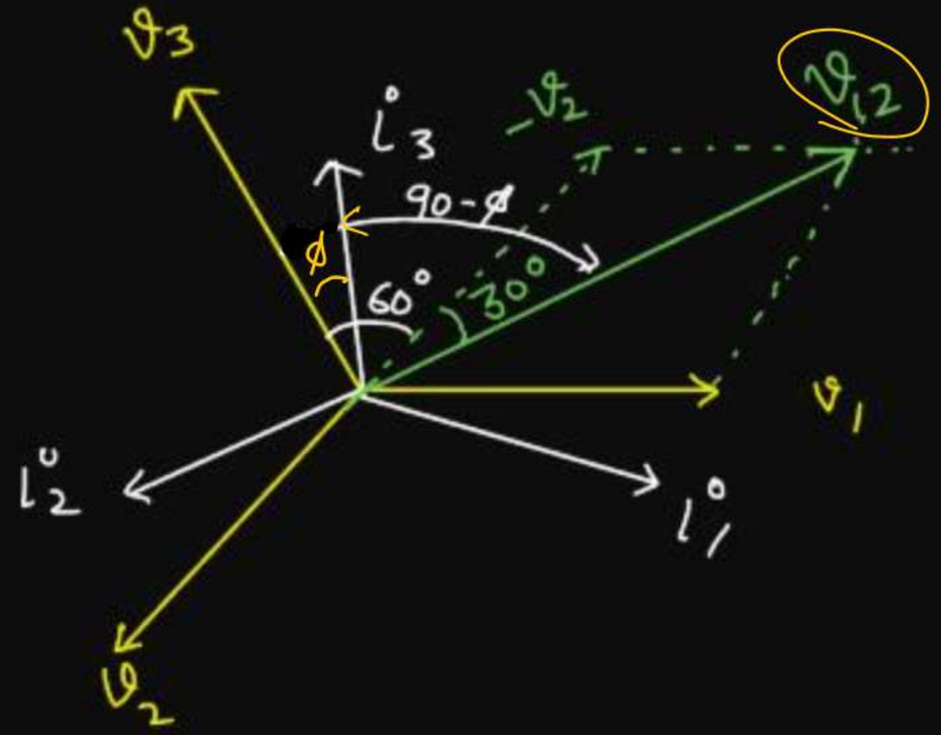
$W = I_3^\circ V_{12} \cos(90-\phi)$ $\quad (V_{12} = V_1 - V_2)$

or

$W = I_3^\circ V_{12} \sin\phi$

or

$W = VI \sin\phi$ = Reactive Power.



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Induction Type Instrument (Single Phase energy Meter)

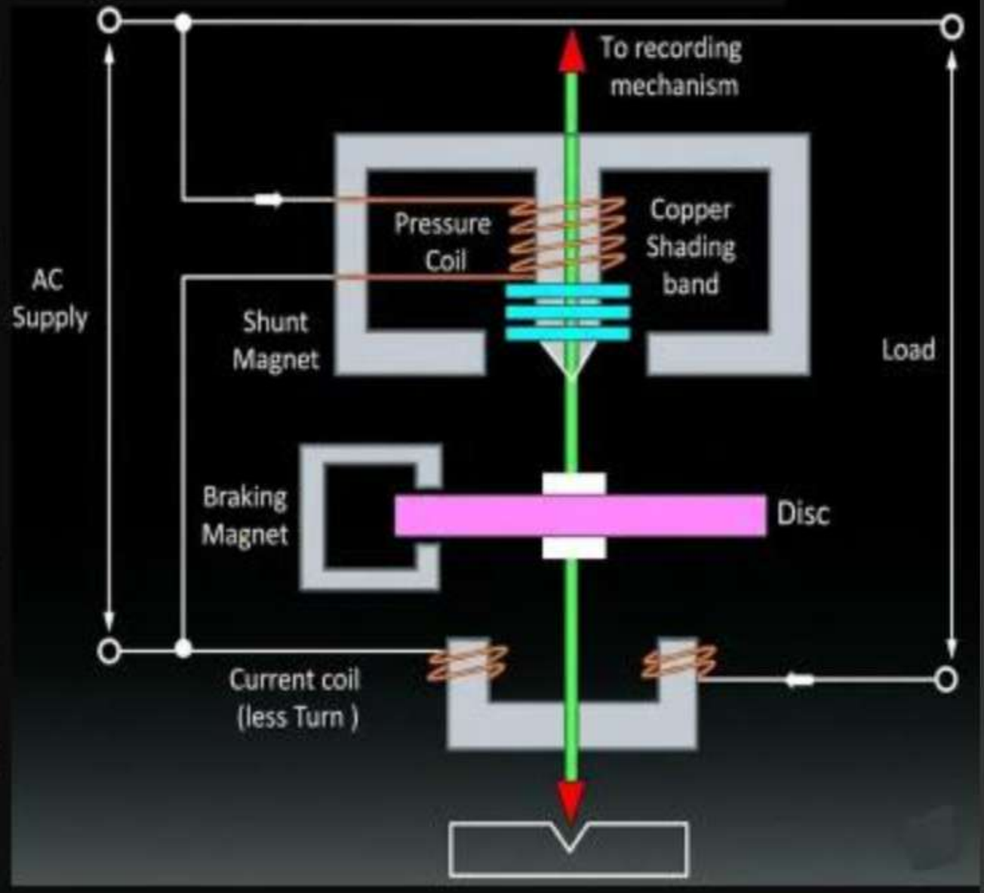
Construction:-

1. Driving System: It produces the torque required to rotate the aluminum disc. Consists of two electromagnets:

Series Magnet (Current Coil): Connected in series with the load and carries load current.

Shunt Magnet (Pressure Coil): Connected across the supply voltage.

Working: The alternating fluxes produced by the two magnets induce eddy currents in the aluminum disc. Interaction between these fluxes and eddy currents produces **driving torque**. The driving torque is proportional to power consumed.



2. Moving System The moving system rotates under the action of the driving torque. A lightweight aluminum disc mounted on a spindle. The spindle is supported by bearings to reduce friction.

Working: Eddy currents induced in the disc interact with magnetic fields. As a result, the disc rotates at a speed proportional to the power consumed.

Induction Type Instrument (Single Phase energy Meter)

AKTU-2025-26

3. Braking System:- The braking system controls the speed of the rotating disc. It Consists of a **permanent magnet** placed near the edge of the aluminum disc.

Working: When the disc rotates through the magnetic field of the permanent magnet, eddy currents are induced in the disc. These eddy currents produce a braking torque that opposes the motion. Braking torque is proportional to the speed of the disc.

4. Registering System: The registering system records the energy consumed. A gear train connected to the spindle. Counting mechanism with dials or digital register.

Working: The rotating disc drives the gear train. The gear train operates the counting mechanism. The reading is displayed in **kilowatt-hours (kWh)**, also called **units of electrical energy**.

Working: The meter works on the principle of **electromagnetic induction**. The interaction of magnetic fluxes produced by the current coil and pressure coil induces eddy currents in an aluminum disc, producing a driving torque that rotates the disc.

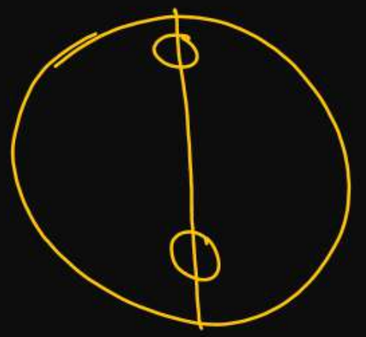
Induction Type Instrument

AKTU-2025-26

Creeping is the continuous slow rotation of the disc of an induction-type energy meter even when no load is connected (i.e., current coil carries no current, but the voltage coil is energized).As a result, the meter records energy consumption even when no electrical energy is being used, leading to measurement errors.

Causes of Creeping

- Excessive supply voltage above the rated value.
- Overcompensation for friction in the meter.
- Stray magnetic fields affecting the meter.
- Vibrations or mechanical defects in the meter.
- Incorrect adjustment of the braking magnet.



Prevention of Creeping

Drilling two diametrically opposite holes in the aluminum disc: When one of the holes comes under the shunt magnet, the disc stops rotating.

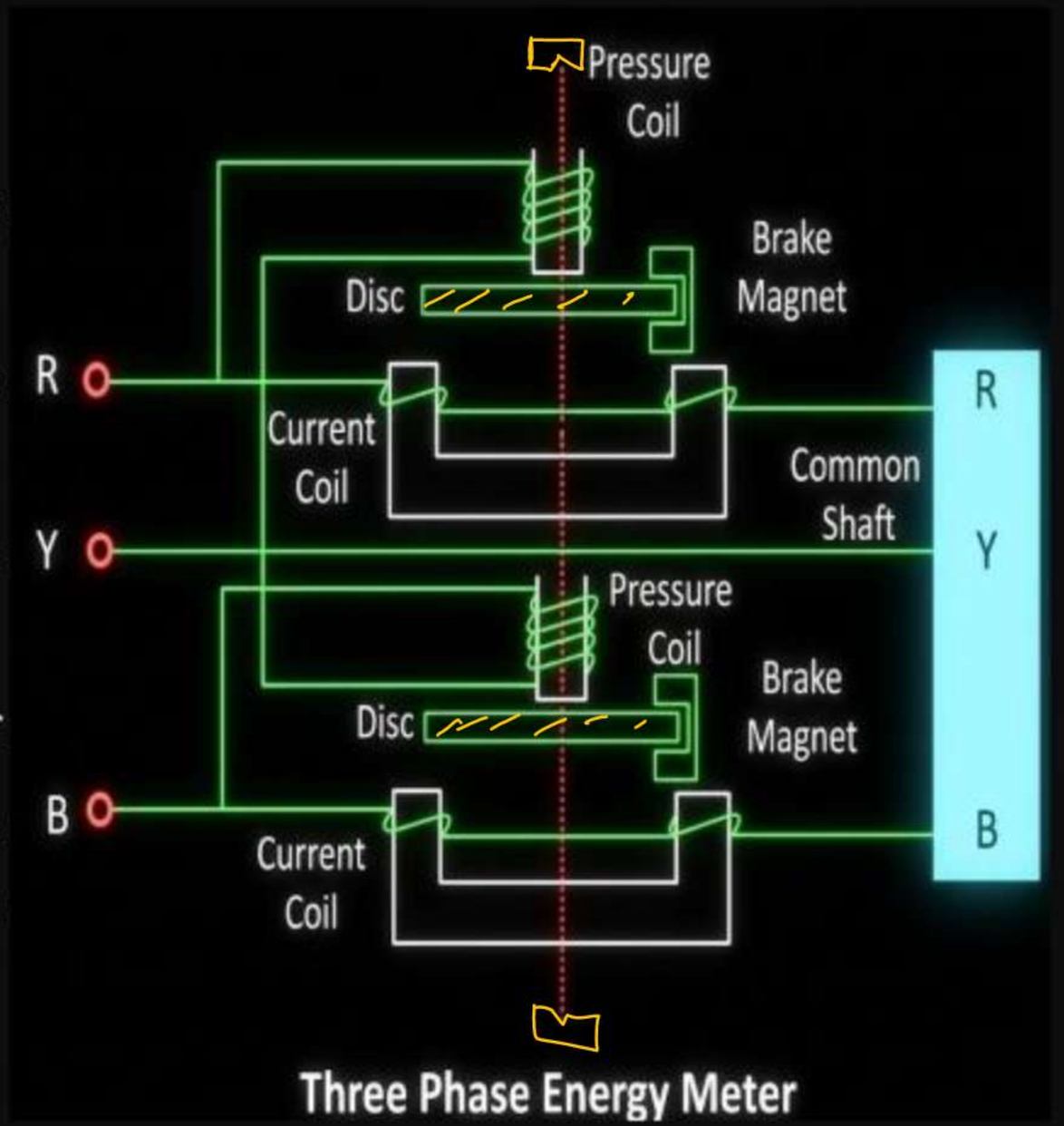
Fixing a small piece of iron (or a magnetic strip) on the edge of the disc: The iron piece is attracted by the braking magnet and prevents further rotation when there is no load.

Induction type Energy Meter

AKTU-2025-26

Three phase Energy Meter :-

- It has two discs mounted on the common shaft.
- Both the disc has its braking magnet, copper ring, shading band and the compensator for getting the correct reading.
- The two elements are used for measuring the three phase power.
- It is essential that the driving torque of both element must equal for equal amount of power passing through them.
- The torque is adjusted by connecting the current coils of both the elements in the series and their potential coils in parallel. The full load current is passed through the coil due to which the two opposite torque is set up in the coil.



Three Phase Energy Meter

Induction type Energy Meter

Three phase Energy Meter :-

- The strength of both the torques are equal, and hence they do not allow the disc to rotate.
- If the torque becomes unequal and the disc rotates then the magnetic shunt is adjusted. The balance torque is obtained before testing the meter.

- **Working :-**
- When the load is connected to the meter both the pressure coil and the current coil of the two elements mounted on the shunt and series magnet produces magnetic flux.
- This flux when links with the discs cause an eddy current to flow in it.
- Interaction of eddy currents with the flux imposed by the two coils causes the production of torque on discs.
- Since two discs are attached to one spindle, the torque exerted on the two discs added mechanically.
- Hence, rotation of the shaft gives the 3-phase energy consumed.

Imp Q. ④

Measurement of power Factor

AKTU-2024-25, 2023-24

The power factor meter are of two types.

Electrodynamometer type

opt

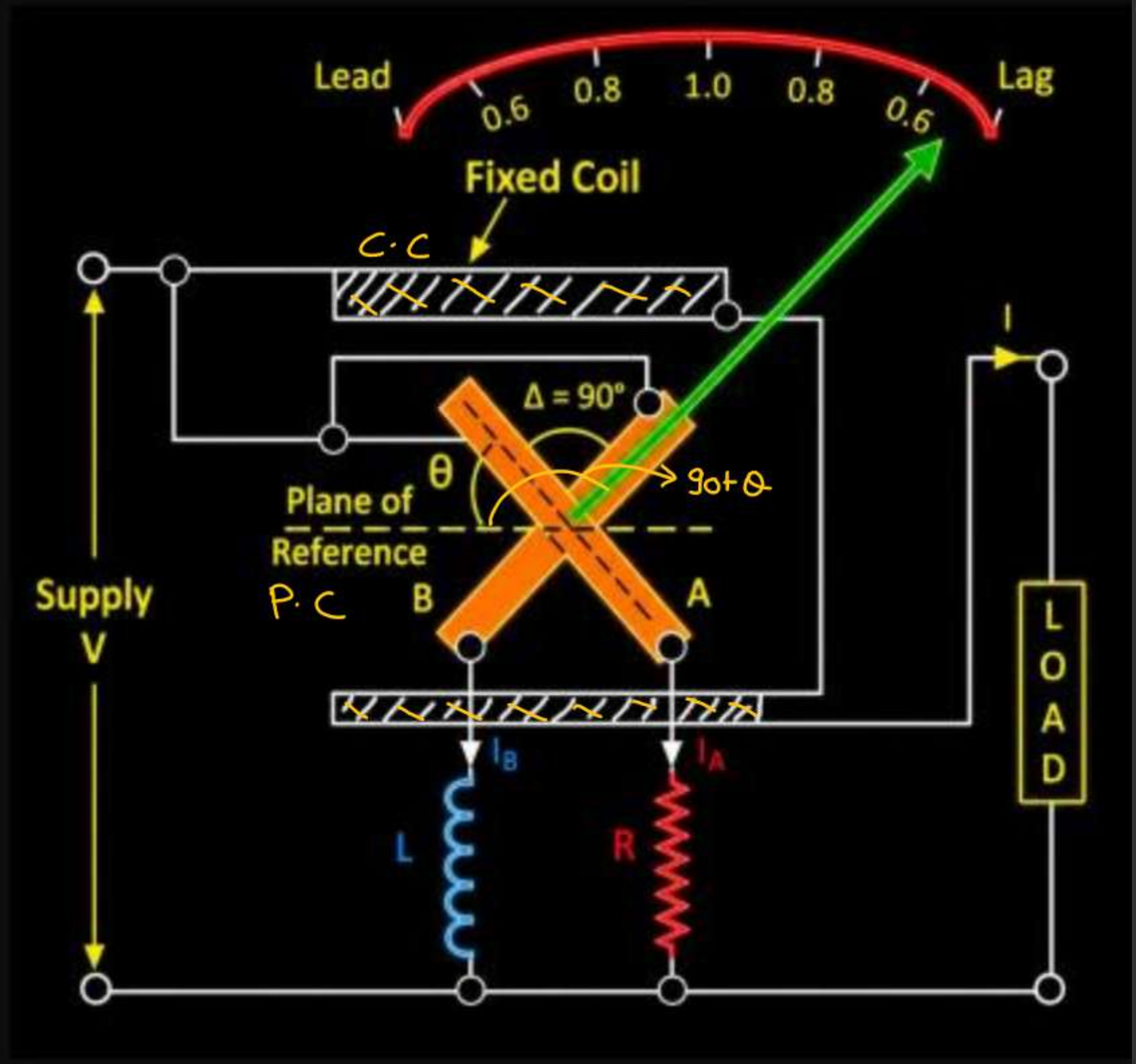
- (i) Single Phase Electrodynamometer
- (ii) Three Phases Electrodynamometer

Moving Iron Type Meter

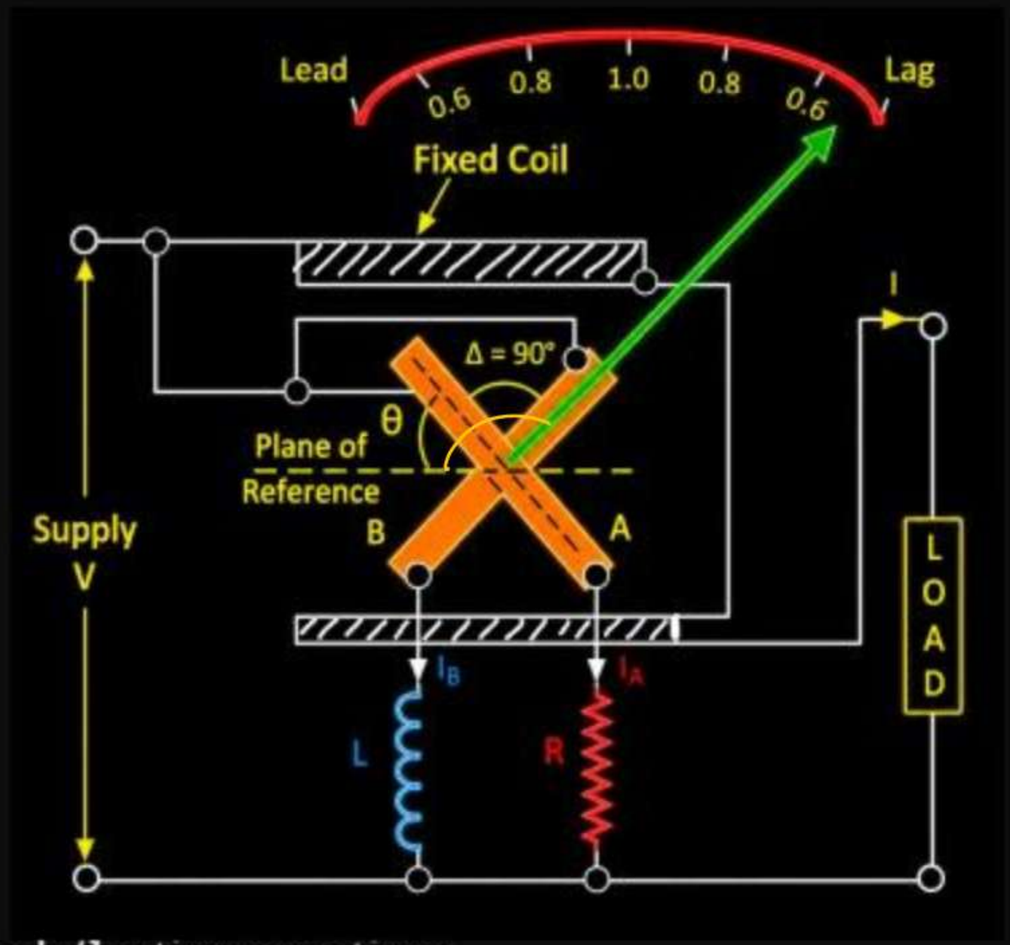
Rotating Iron Magnetic Field

Electrodynamometer type power factor Meter
(single phase Electrodynamometer)

- The meter has fixed coil which acts as a current coil. This coil is split into two parts and carry the current under test.
- The magnetic field of the coil is directly proportional to the current flow through the coil.
- The meter has two identical pressure coils A and B. Both the coils are pivoted on the spindle.
- The pressure ***coil A*** has no inductive resistance connected in series with the circuit.
- ***Coil B*** has highly inductive coil connected in series.
- The current in the coil A is in phase with the circuit while the current in the coil B lag by the voltage nearly equal to 90°.
- The connection of the moving coil is made through silver or gold ligaments.



Electrodynamometer type power factor Meter (single phase Electrodynamometer)



Working:-Deflecting torque acting on the coil A is given as

$$T_A = KVIM\cos\varphi \sin\theta$$

θ – angular deflection from the plane of reference.

M_{max} – maximum value of mutual inductance between the coils.

This torque say act in the clockwise direction.

The deflecting torque acting on coil B is,

$$T_B = KVIM_{max}\cos(90-\varphi)\sin(90+\theta)$$

$$T_B = KVIM_{max}\sin\varphi\cos\theta$$

The value of maximum mutual inductance is same between both the deflecting equations.

At equilibrium we have both the torque as equal thus on equating

$$T_A = T_B$$

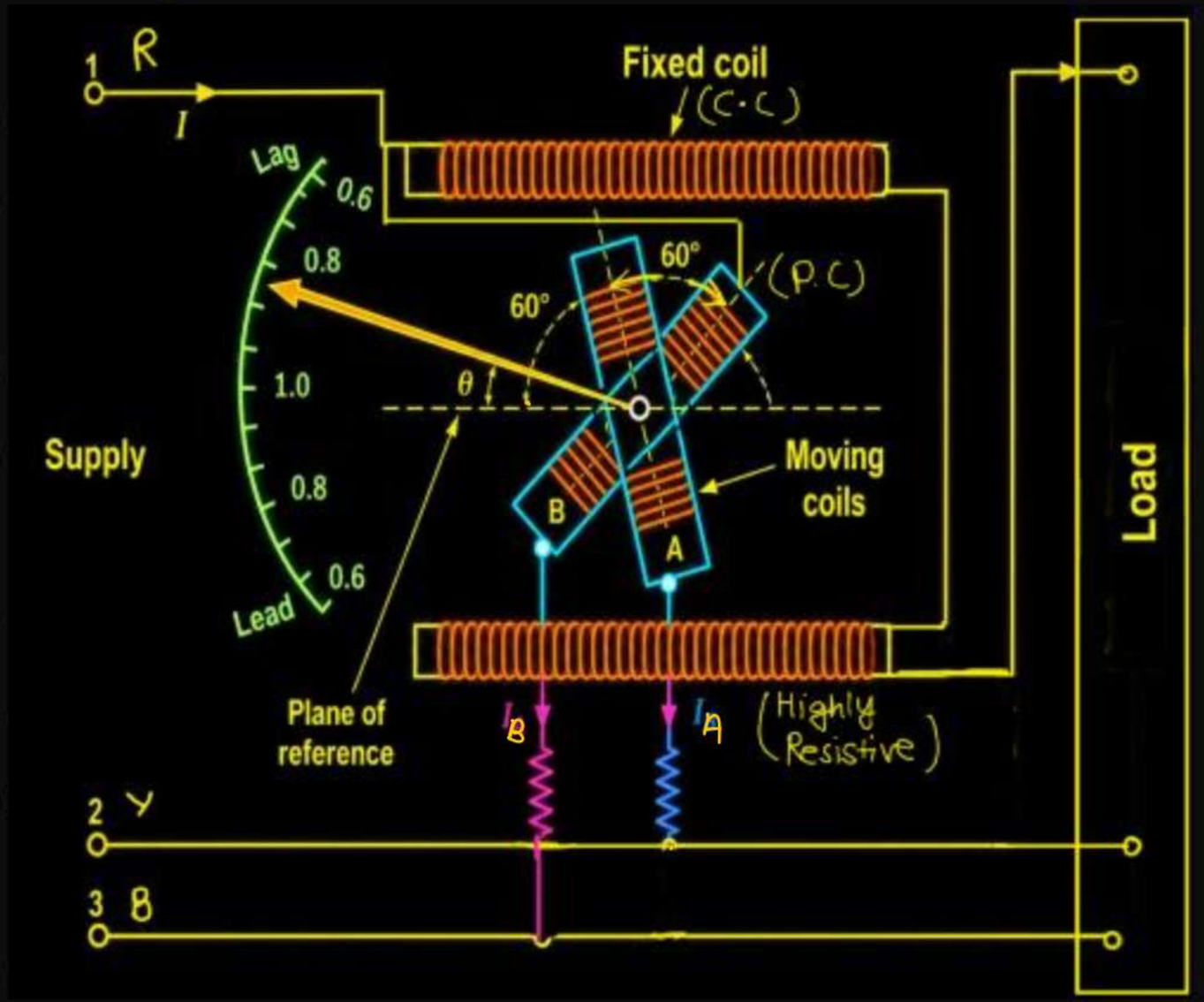
$$\Phi = \theta$$

the deflection angle is the measure of phase angle of the given circuit.

Electrodynamometer type power factor Meter
(Three phase Electrodynamometer)

Construction:-

- The construction of a 3-phase electrodynamic power factor meter is almost the same as for a single phase instrument.
- The two fixed coils (current coils) are connected in series with one phase and carry the line current I.
- The two moving coils A and B are fixed at 120° to each other and are connected across two different phases through high non-inductive resistances.
- coil A is connected across R and Y and coil B across R and B



Torque Equation :-

For Coil A , Voltage $V_{RY} = V_R - V_Y$

Current $I_R = I_A$

For Coil B

Voltage $V_{RB} = V_R - V_B$

Current $= I_B$

Torque on A

$$T_A \propto I_A \cdot I \cos(30+\phi) \sin(60+\theta)$$

Torque on B

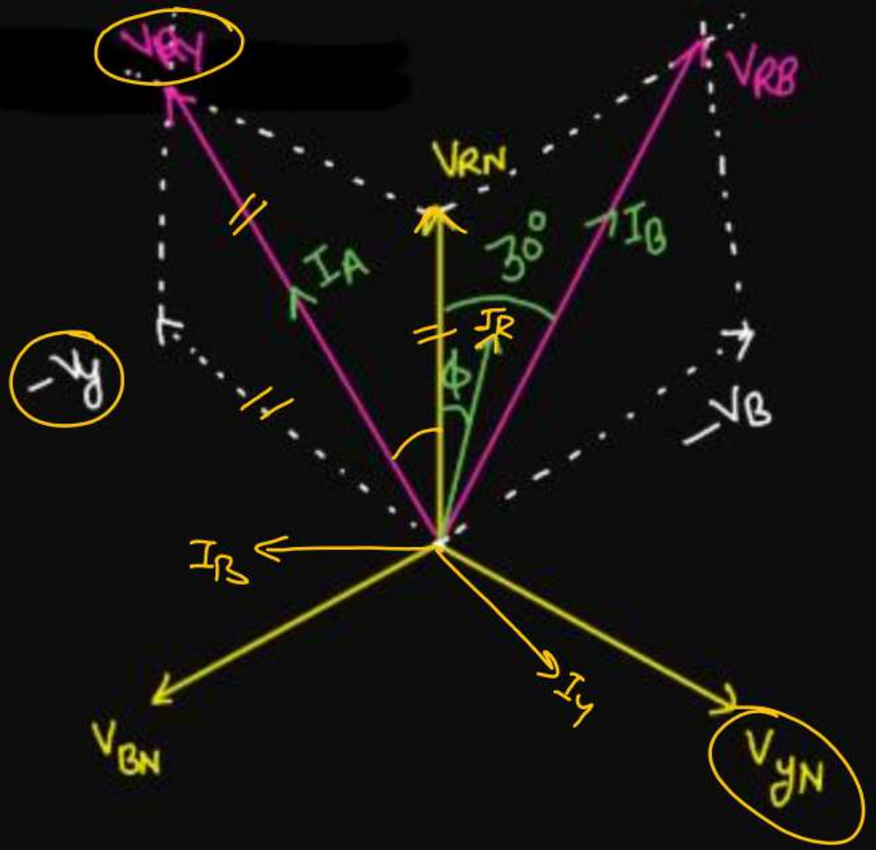
$$T_B \propto I_B I \cos(30-\phi) \sin(60-\phi)$$

On Equillibrium $T_A = T_B$

$$I_A I \cos(30+\phi) \sin(60+\theta) = I_B I \cos(30-\phi) \sin(60-\phi)$$

$$\theta = \phi$$

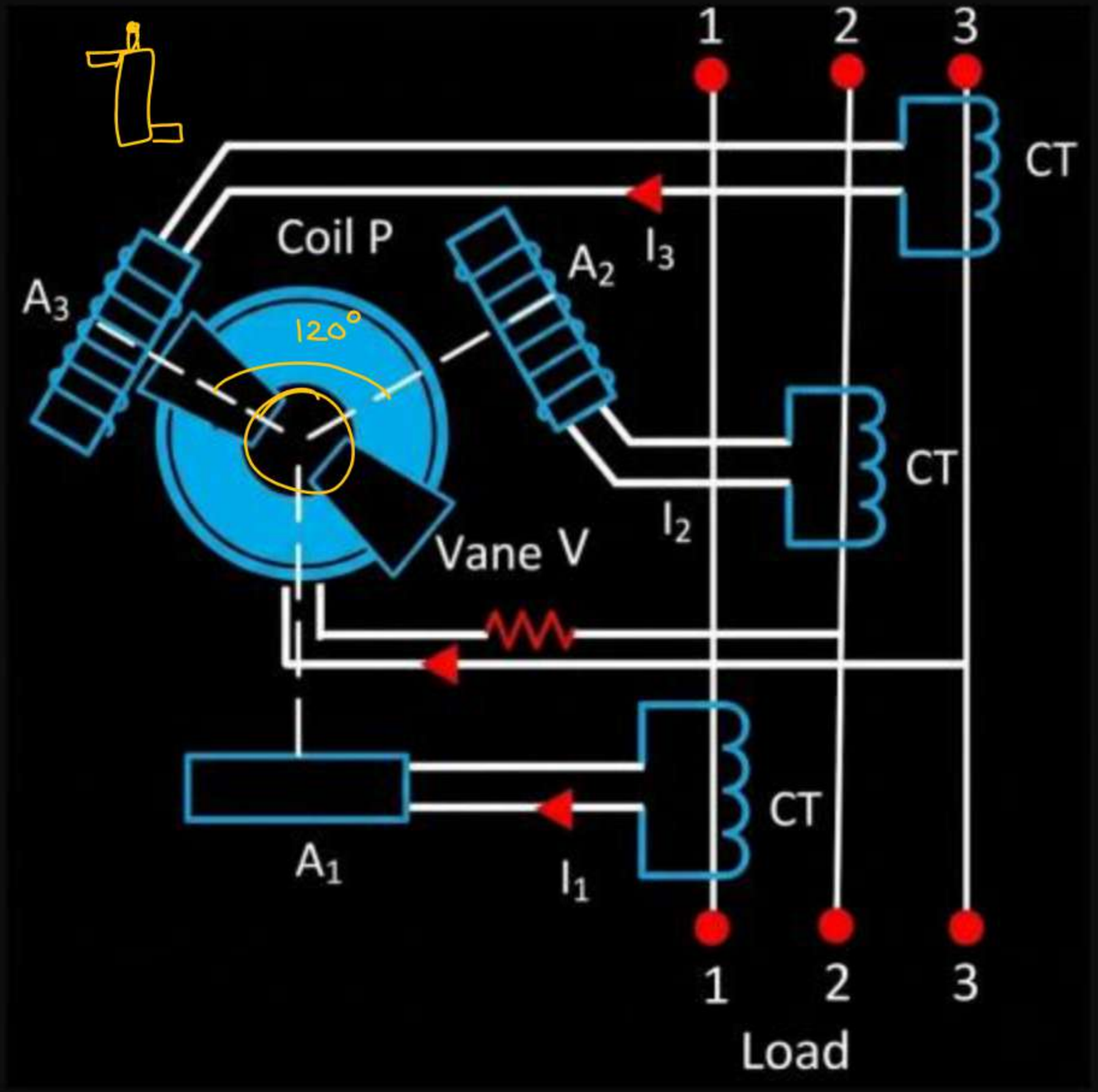
So deflection is equal to the phase angle.



Rotating Iron Magnetic Field type power factor Meter

Theory:-

- The power factor meter has three fixed coils, and their axes are 120° displaced from each other.
- The coils are connected to the three phase supply with the help of the current transformer.
- The P is the fixed coil connected in series with the high resistance circuit across the phases 2 and 3.
- There is an iron cylinder across coil P.
- The two iron vanes are fixed to the cylinder.
- The spindles also carry damping vanes and pointer.



Angle between

V_{23} . I_1 → $90-\phi$

V_{23} I_2 → $330-\phi$

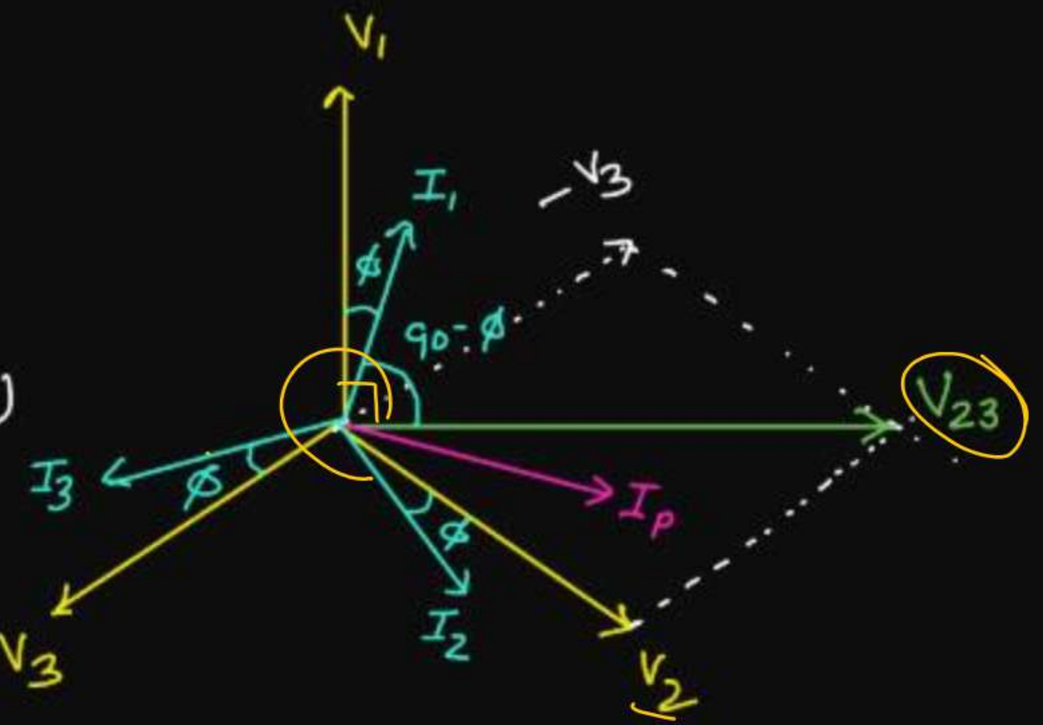
V_{23} I_3 → $270-\phi$

Deflecting Torque

$$T_d \propto \left[I_1 I_p \cos(90-\phi) \sin(90+\theta) + I_2 I_p \cos(330-\phi) \sin(210+\phi) + I_3 I_p \cos(270-\phi) \sin(330+\phi) \right]$$

For Equillibrium $T_d = 0$

On Solving $\boxed{\theta = \phi}$



This shows that angle of deflection depends on phase angle ϕ.

V.Imp (5)
Any one or two

Analog Frequency Meter

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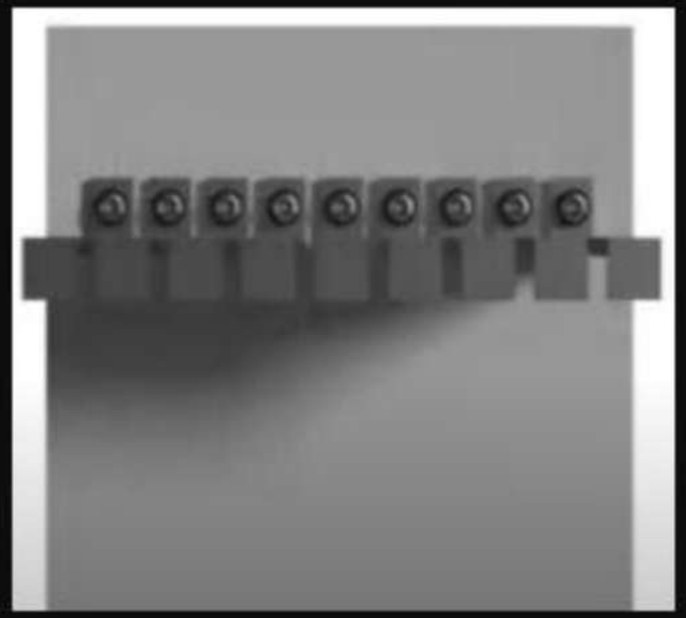
The number of cycle per second of the alternating quantity is known as the frequency. The instruments used to measure frequency called Frequency Meter.

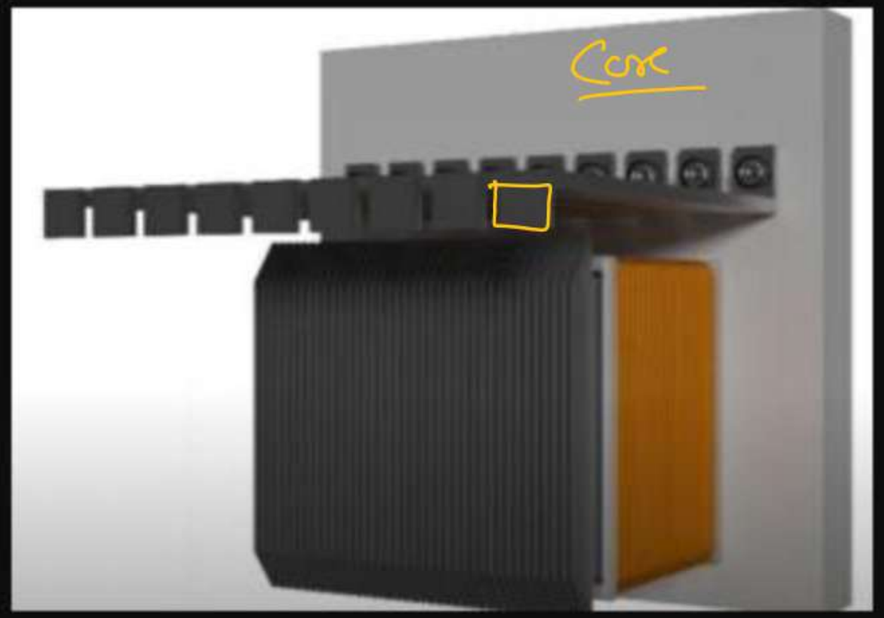
Types of Frequency Meter

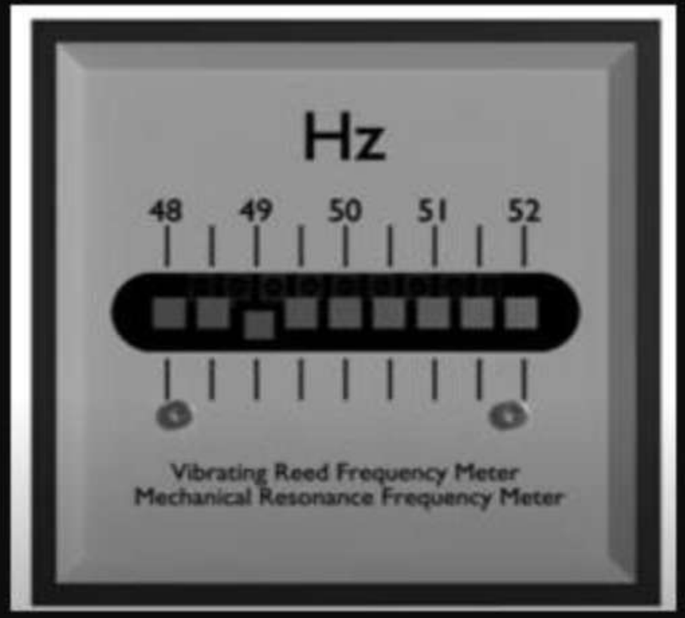
There are the following instruments of determining the frequency.

- Vibrating Reed frequency meter.
- Weston type frequency meter.
- Ferro dynamic type frequency meter
- Ratio meter type frequency meter.
- Electrodynamometer type frequency meter.

Vibrating Reed (mechanical resonance) frequency meter.

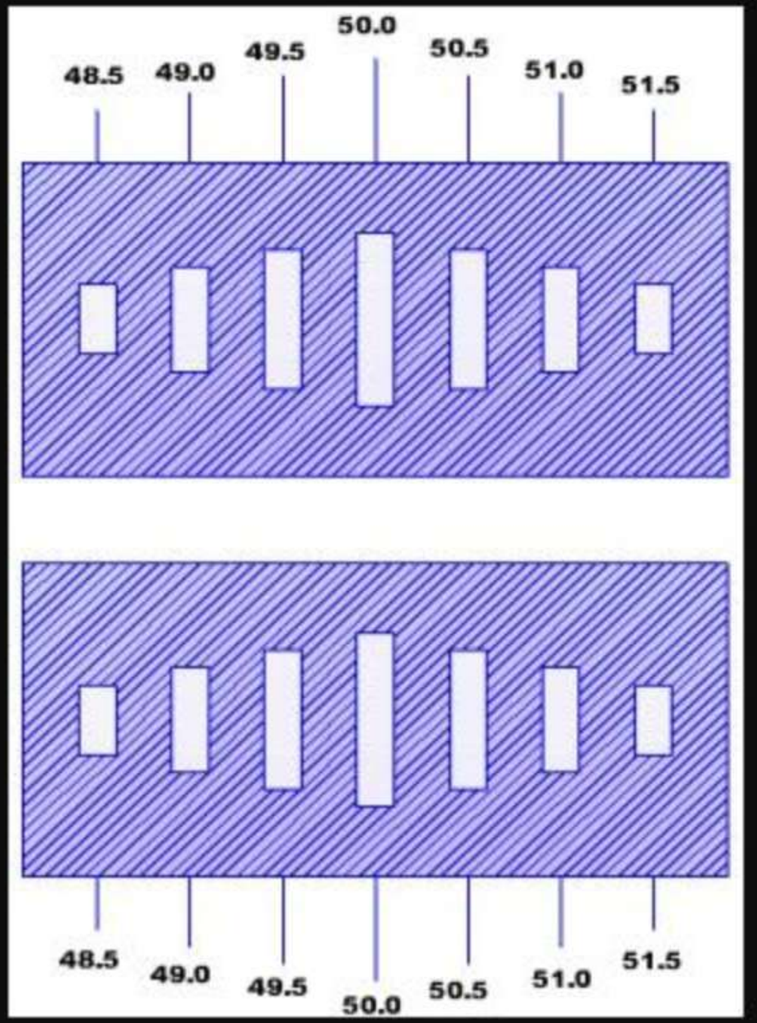






Vibrating Reed (mechanical resonance) frequency meter.

- It consists of 7 vibrating reeds and each vibrating reed has a specific value.
- These reeds vibrate when this frequency meter is connected to supply for the measurement of frequency.
- As a result all the reeds start vibrating. But the reed whose natural frequency is double than frequency of supply will vibrate maximum due to the mechanical resonance.



Vibrating Reed (mechanical resonance) frequency meter.

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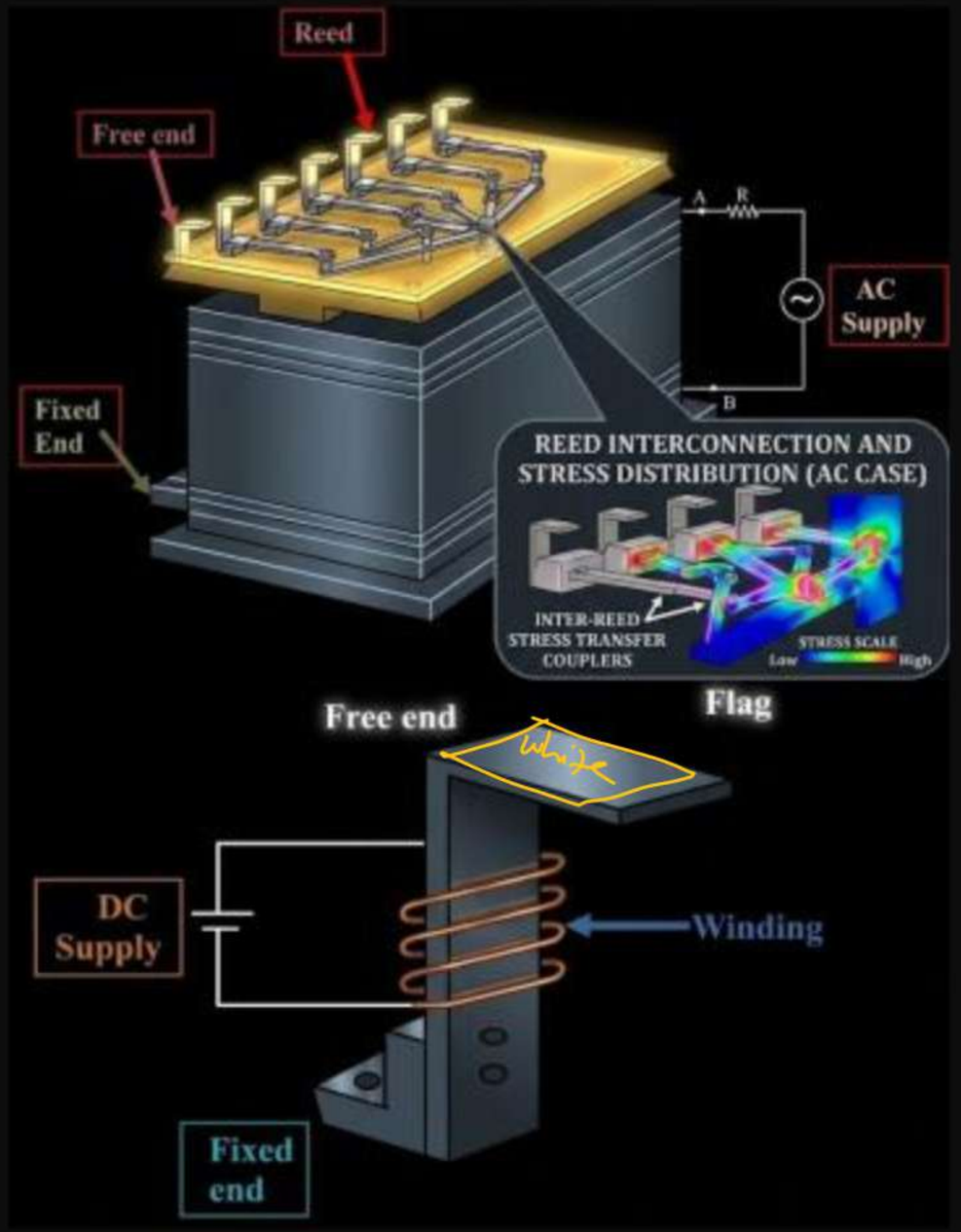
Construction:-

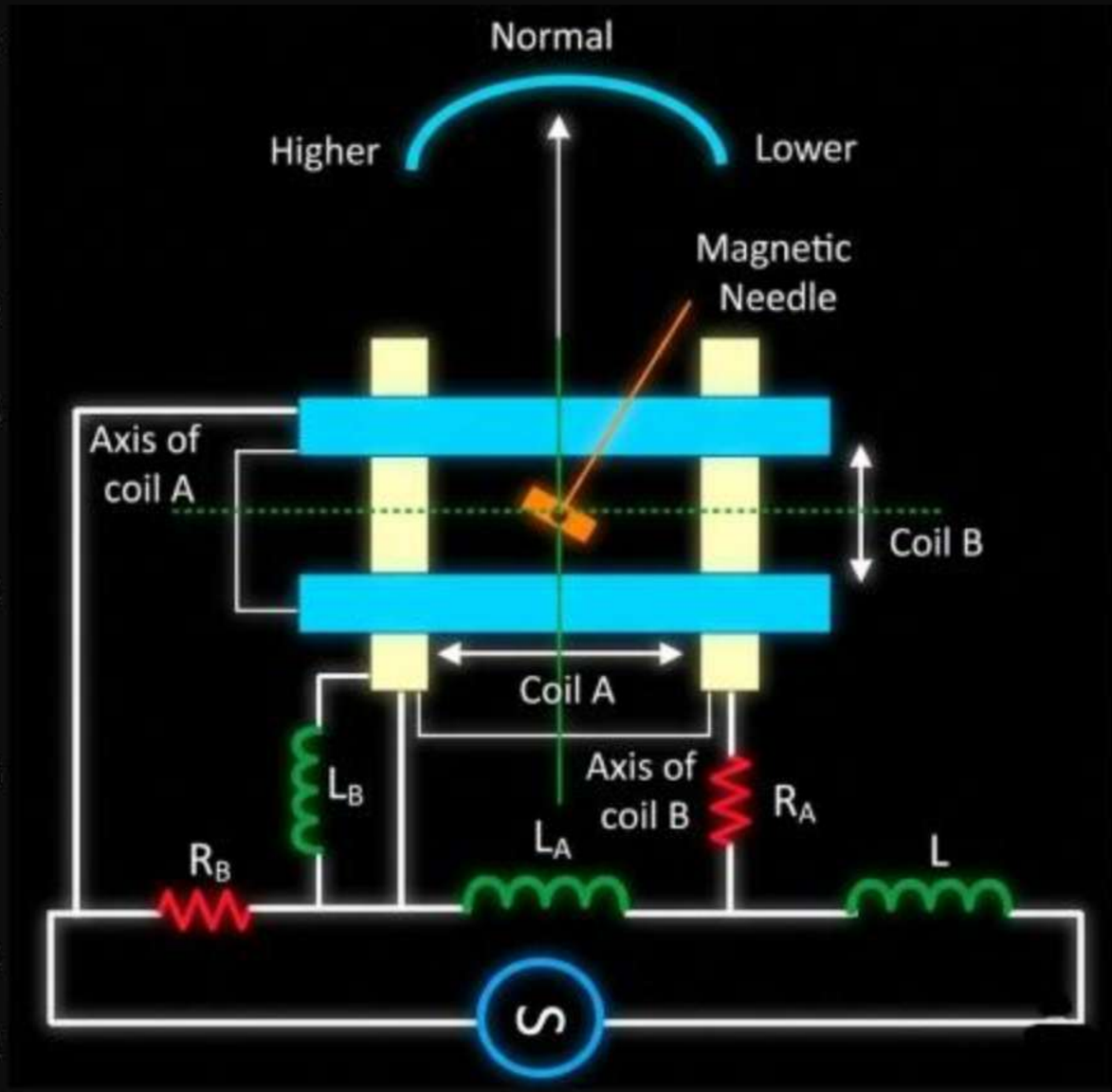
- This frequency meter consists of thin flat steel reeds which are arranged alongside and these reeds are near to the **electromagnet**.
- The electromagnet consists of a laminated **armature** and a **winding** connected with a **resistance** in series on it.
- This winding is connected to the AC supply whose frequency is to be measured. The metallic reeds are 4mm wide and 0.5 mm thick.
- These metallic reeds are arranged in a row and consists of flexible base and these bases carries armature of the electromagnet. These reeds are colored with white color.



Weston type frequency meter.

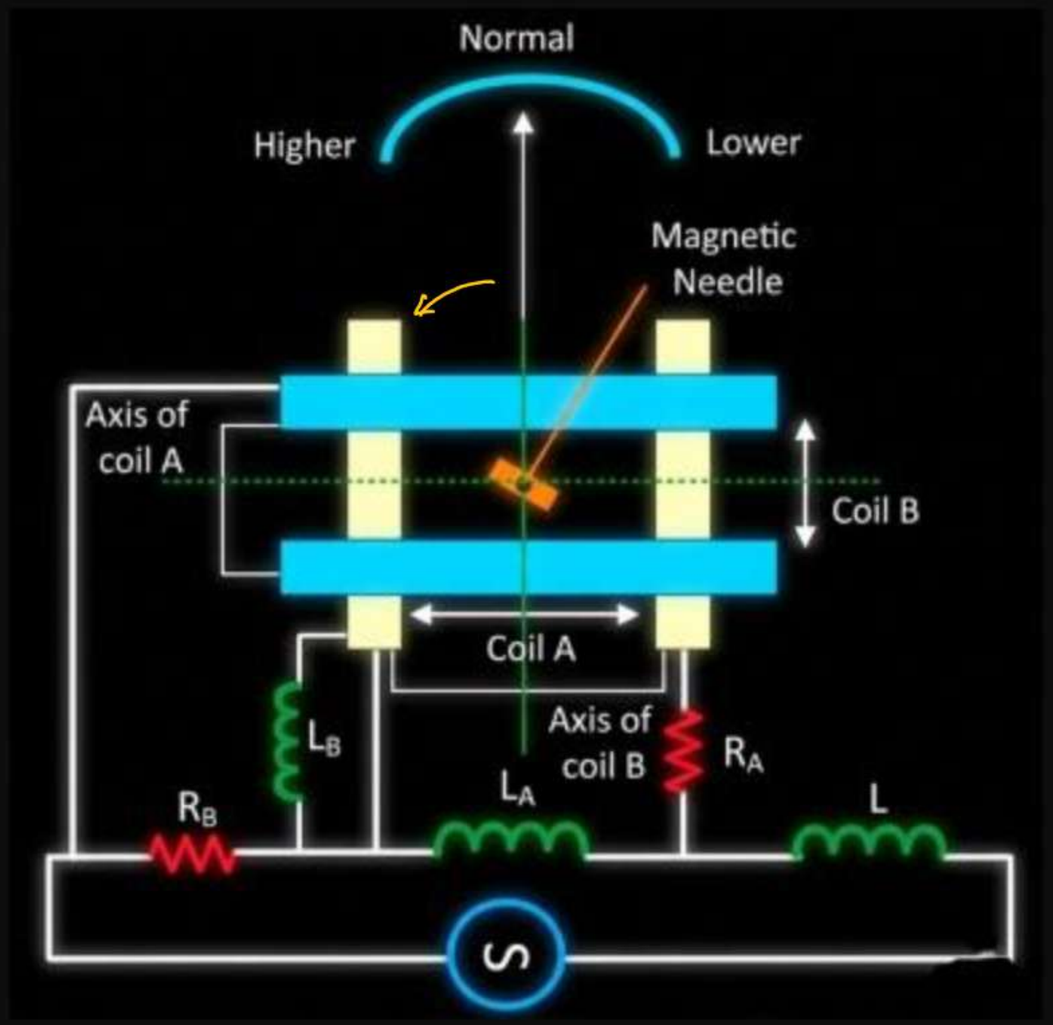
Construction:-

- It consists of two coils, coil-A and coil-B (each divided into two parts) which are placed perpendicular to each other.
- At the Centre, a needle made up of soft iron material is mounted on a spindle. A pointer is attached to the needle at an angle of 45° and this assembly forms the moving system.
- The resistance R_A is connected across the series combination of coil-1 and inductance L_A.
- The inductance L_B is connected across the series combination of coil-2 and resistance R_B.
- Both these combinations of RA and LB are connected in series and they are connected to the supply through harmonic damping inductor L.



Weston type frequency meter.

Working:- Works on the principle of variation in inductive reactance with frequency.

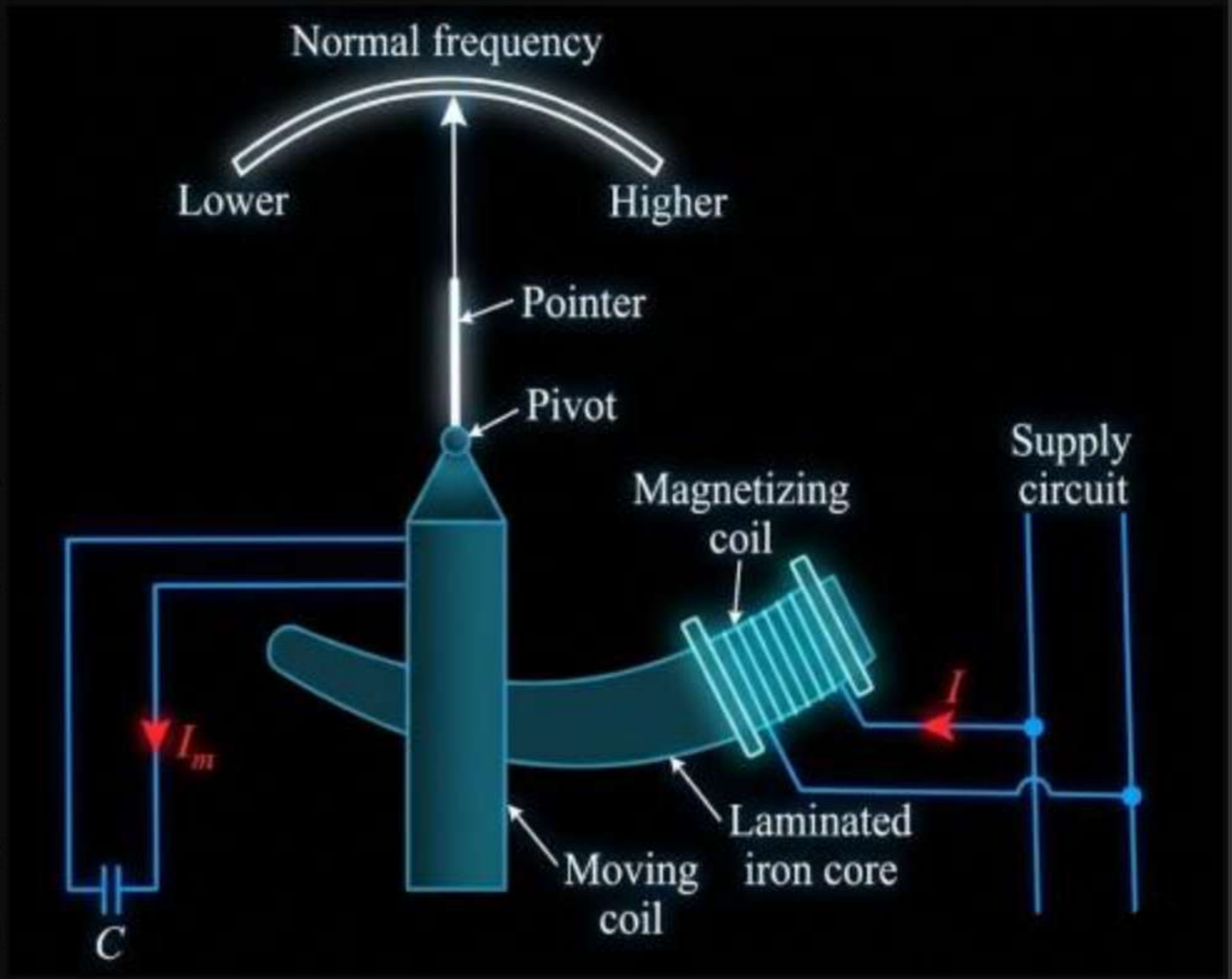


- At normal supply frequency, the current through both the coils will be equal and the magnetic fields setup by them will be perpendicular to each other.
- So, the needle takes up a position where both the fields cancels each other (45° from the axis of both coil).
- Hence the needle rests in that position and the pointer will be at centre of the scale, indicating the normal frequency.
- If the supply frequency is more than normal value, then the reactance's due to L_A and L_B increase.
- This increases the current through coil-A (as L_A is in series) and reduces through coil-B (as L_B is in parallel). Hence the field of coil-A becomes stronger than that of coil-B and so the needle deflects towards the axis of coil-A and the pointer indicates the corresponding lower frequency.

Electrical Resonance type Frequency Meter

Construction:-

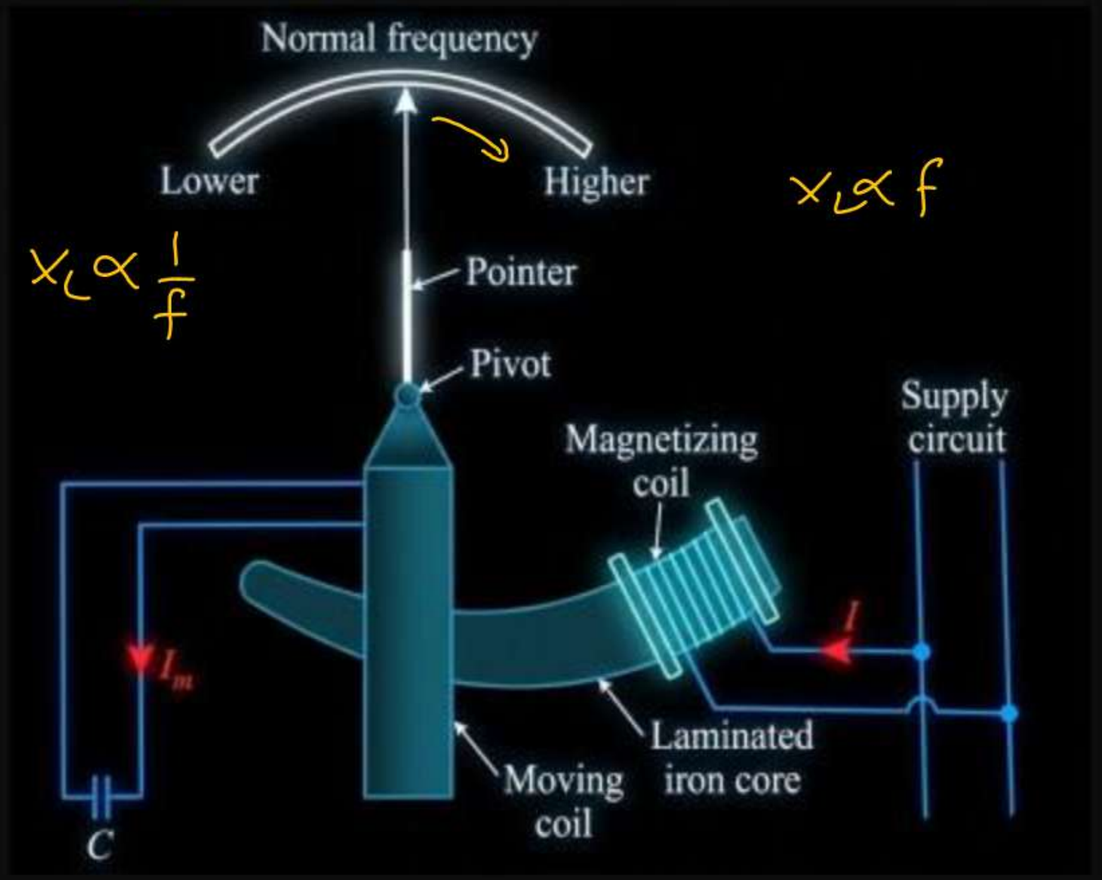
- It consists of a fixed coil which is connected across the supply whose frequency is to be measured. This coil is called magnetizing coil.
- The magnetizing coil is mounted on a laminated iron core. The iron core has a cross-section which varies gradually over the length, being maximum near the end where the magnetizing coil is mounted & minimum at the other end.
- A moving coil is pivoted over this iron core.
- A pointer is attached to the moving coil. The terminals of the moving coil are connected to a suitable capacitor C.



Electrical Resonance type Frequency Meter

Working:-

- Fixed coil is connected with supply whose frequency is to be measured.
- Moving coil moves to a position where inductive reactance become equal to the capacitive reactance .
- inductive reactance of moving coil is dependent of its position w.r.t. to the fixed coil.
- It is maximum when it is near from fixed coil and vice versa.



- When frequency increases X_c decrease and moving coil then move away from fixed coil and attain a position such that X_L decreases and comes equal to X_c and resonance establish.
- When frequency decreases X_c increase and moving coil then moves near from fixed coil and attain a position such that X_L increases and comes equal to X_c and resonance establish.

Ratio meter type frequency Meter

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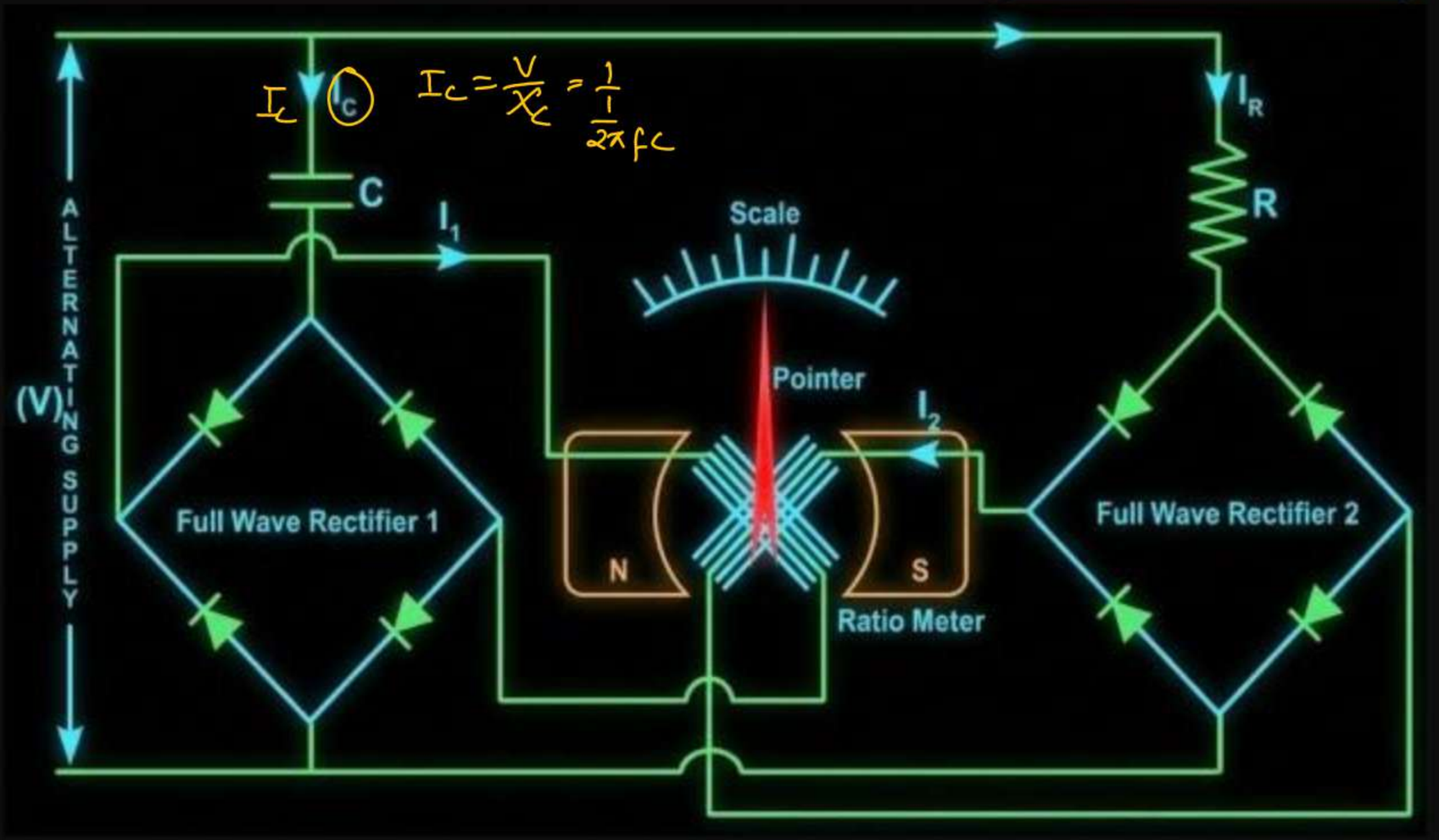
Theory:-

- A ratio meter type frequency meter consists of a ratio meter.
- This ratio meter gives a relationship between the current ratio and the deflection.
- There are two coils in the ratio meter. We fit them perpendicular to each other.
- This frequency meter also consists of two bridge rectifiers. These two rectifiers feed the ratio meter coils.



Rotating Iron Magnetic Field type power factor Meter

Theory:-•Let us consider V is the supply voltage. Also, we consider f is the supply frequency. Again we consider I_1 is the output current of the first rectifier and I_c is the input current of that rectifier.

•As the input path of the first rectifier is capacitive. $I_c = 2\pi f C V$

•Again, the output current of a rectifier is proportional to its input current.

$$I_1 \alpha I_c .$$

$$I_1 \alpha 2\pi f C V$$

•On the other hand, in the second rectifier, the input current is proportional to V/R. Therefore, the output current is also proportional to V/R.

$$\frac{I_1}{I_2} = \frac{2\pi f C V}{V/R} = 2\pi f C \cdot R$$

$$I_2 \alpha I_R \alpha V/R$$

•In a ratio meter type instrument, the deflection angle (θ) is proportional to the ratio of the current of two coils. Therefore,

$$\theta \alpha I_1/I_2 ,$$

$$\theta \alpha 2\pi f C R$$

$$\theta \propto \frac{I_1}{I_2} \propto f$$

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